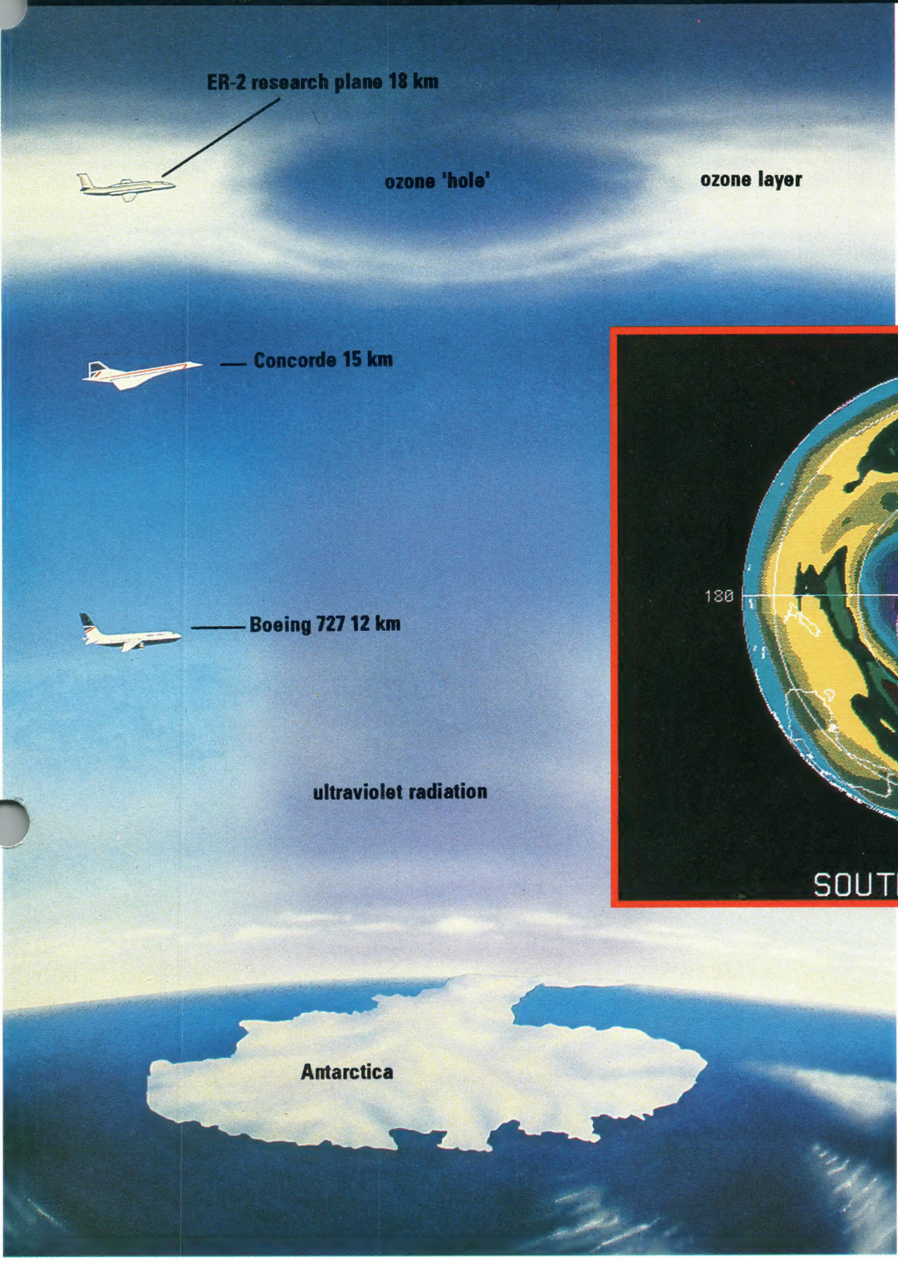
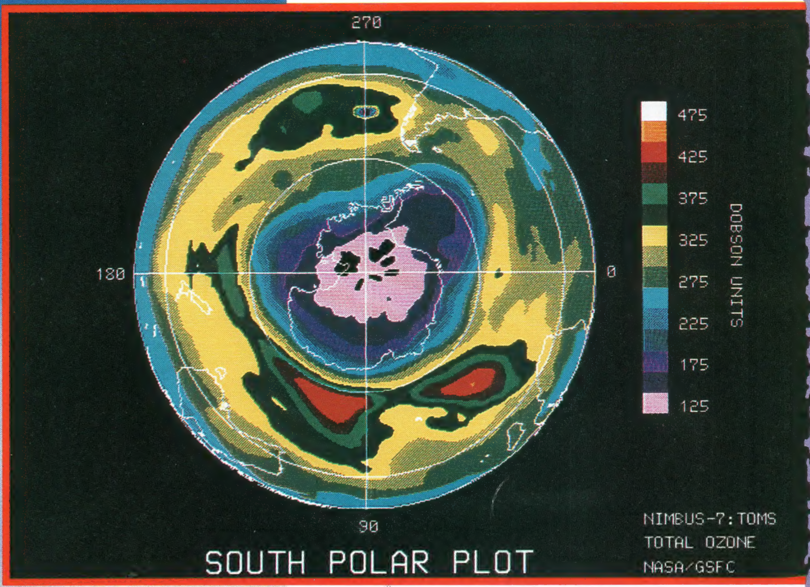
MAKING RAIN　THE HEAT TRAP　HOLE IN THE SKY

MANIPULATING Weather





Michael Gilbert/SPL Inset NASA

***Sunny weather** may become a bane if the ozone layer is further damaged by human pollution, allowing more UV light to reach the ground. Already a 'hole' appears over Antarctica in the southern spring, showing up as the purple-bounded area in the satellite map (inset above).*

HUMAN BEINGS MANIPULATE the weather both intentionally and unintentionally. So far, people have done little of the former but, potentially, a great deal of the latter. A growing number of scientists fear that our industrial activity will change weather and climate – with disastrous effects.

To date, most attempts to make a short-term change in the weather have been confined to 'seeding' clouds by scattering crystals of silver iodide into them. This can cause rain to fall. The crystals act as 'condensation nuclei' on which tiny water droplets form. These then collide, forming larger drops that fall as rain.

This technique has also been used to try to modify violent tropical storms. When forecasters predicted that a depression might grow into a hurricane, planes were sent to drop the crystals over the clouds near the centre of the wind system. The rain that was triggered fell through up welling warm air currents, cooled them and possibly prevented the storm clouds from building up to a dangerous extent.

Tree planting

Trees affect the weather in several ways. At the 'micro' levels they can act as windbreaks, preventing valuable topsoil from being blown away. Trees also give out large amounts of water vapour from their leaves and this can moisten the air sufficiently to increase the rainfall locally. On the arid eastern side of the Mediterranean island of Crete, for example, the Greek government

NASA/SPL

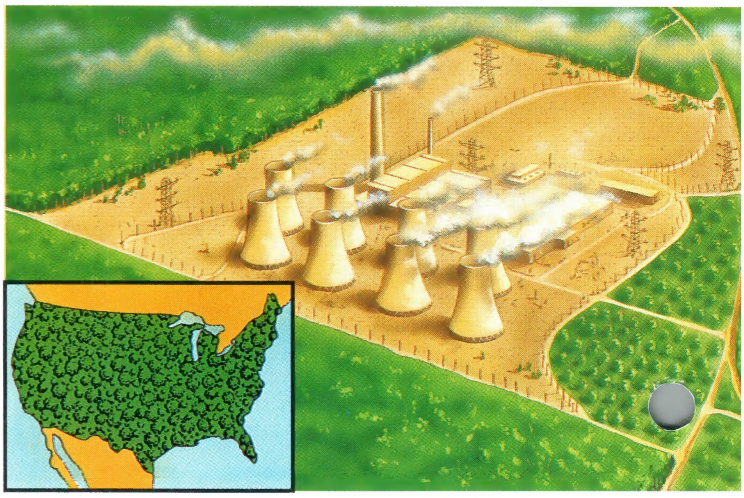
***On board a NASA 'laboratory'** plane over Antarctica, a scientist studies measurements of ozone and other atmospheric gases.*

SMOKE TRAP

Car exhaust fumes and factory smoke tend to rise because they are generally warmer than the surrounding air. The temperature of the air normally falls with increasing height, so the polluting gases tend to rise to a considerable height before they are dispersed. However, unusual weather conditions can sometimes form a 'temperature inversion', in which a layer of warmer air lies above cooler air near the ground. Fumes are then trapped at ground level and are liable to form smog (a mixture of smoke and fog). This is not just unpleasant, but potentially deadly to people with respiratory ailments. Los Angeles is famous for its smogs, which are largely due to its heavy road traffic.


Hutchison Library

Felling rain forests for timber, as here in Zaire, threatens to cause a rise in the global levels of atmospheric CO_2.


Chris Lyon

To absorb CO_2 from a new coal-burning electricity plant in Guatemala, its builders are partly funding the planting of 52 million trees. It would take a forest the size of the USA, excluding Alaska, to absorb world output of CO_2.

is planting trees to increase rainfall and thus promote agriculture.

There is a longer-term reason for planting trees. Like all plants they absorb carbon dioxide; this is one of the major gases involved in the 'greenhouse effect', which *may* be causing the world to warm up.

The greenhouse effect

The greenhouse effect is the trapping of the Earth's heat by the atmosphere, which keeps the Earth about 33°C hotter than it would otherwise be. The glass of a greenhouse acts similarly – it lets visible light through to warm the interior of the greenhouse, but traps the heat radiation that tries to escape.

The various gases making up the atmosphere contribute to the greenhouse effect by different amounts. The most important is carbon dioxide, which is released when any fossil fuel (such as oil, wood, gas, coal or charcoal) is burned to provide heat or light, and when trees are burned to clear forests. To counteract all the carbon dioxide produced by burning fossil fuels, it has been calculated that an additional seven million square km of forest would need to be planted.

There are several other important greenhouse gases. Methane is released in natural gas fields and by bacterial action in the ever-growing number of rice paddy fields. Nitrous oxide is given out in car exhausts. Chlorofluorocarbons (CFCs) are used in spray-can propellants and refrigerator coolants, and for cleaning electrical components.

The extra amounts of these gases put into the atmosphere by human activity may have the effect of raising the mean temperature of the Earth – possibly by 1°C by the year 2025, although scientific opinion is very divided over this.

Such a temperature rise could have devastating effects. The weather might change radically. Deserts could spread further north and south from the equator. The US grain belt might become a dustbowl and the monsoons of the Indian subcontinent and Far East could become more intense.

CFCs probably harm the atmosphere's ozone layer as well. Ozone gas is distributed throughout the atmosphere, but is found in the greatest concentrations 20–30 km up. The ozone layer screens the Earth from much of the ultraviolet present in sunlight. Whenever the weather is sunny, many people take the opportunity to sunbathe and get a tan. It is ultraviolet light that causes tanning, but it ages the skin, and in excess it causes skin cancer.

The ozone hole

In the mid-1980s, the British Antarctic Survey discovered a 'hole' (actually a reduction in concentration) in the ozone layer over the Antarctic. This is primarily caused by CFCs. Reserch has shown that ozone levels in the atmosphere are down, worldwide. This is potentially serious since a one per cent fall in ozone level could cause a five per cent rise in skin cancers.

International efforts have been made to avert this weather threat. In 1987 numerous countries, including the USA, the USSR and Britain, signed the Montreal Protocol on substances that deplete the ozone layer – an agreement to reduce the amount of harmful CFCs released into the atmosphere.

Just amazing!

Paul Raymonde

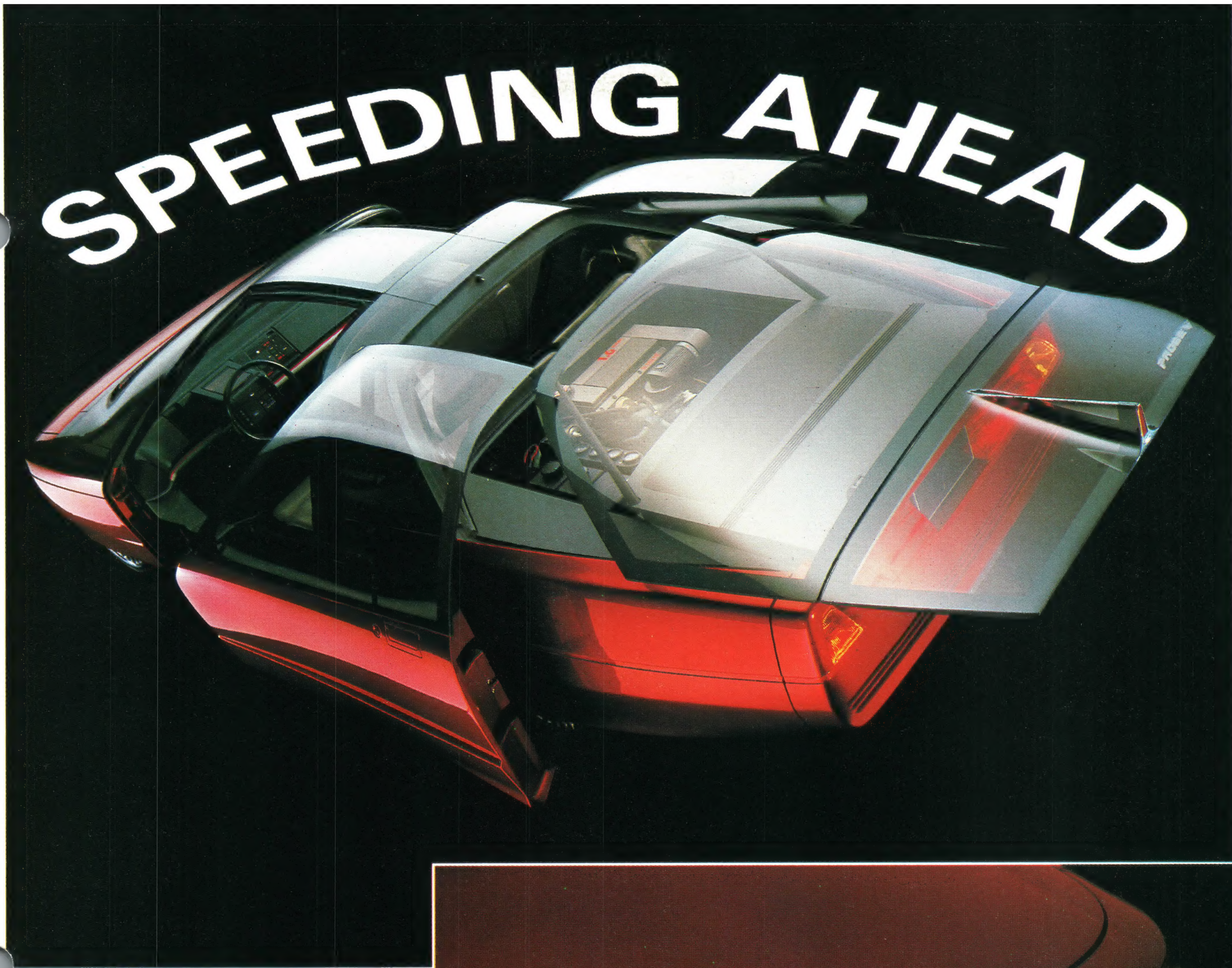
CHILLING PROSPECT

BURNING FOSSIL FUEL COULD COOL THE EARTH, NOT WARM IT, IF THE DUST PRODUCED WERE TO BLOCK OUT SUNLIGHT. THE TEMPERATURE FALL COULD RESULT IN ICE-SHEETS ALL OVER THE NORTHERN HEMISPHERE, STRETCHING AS FAR SOUTH AS LONDON.

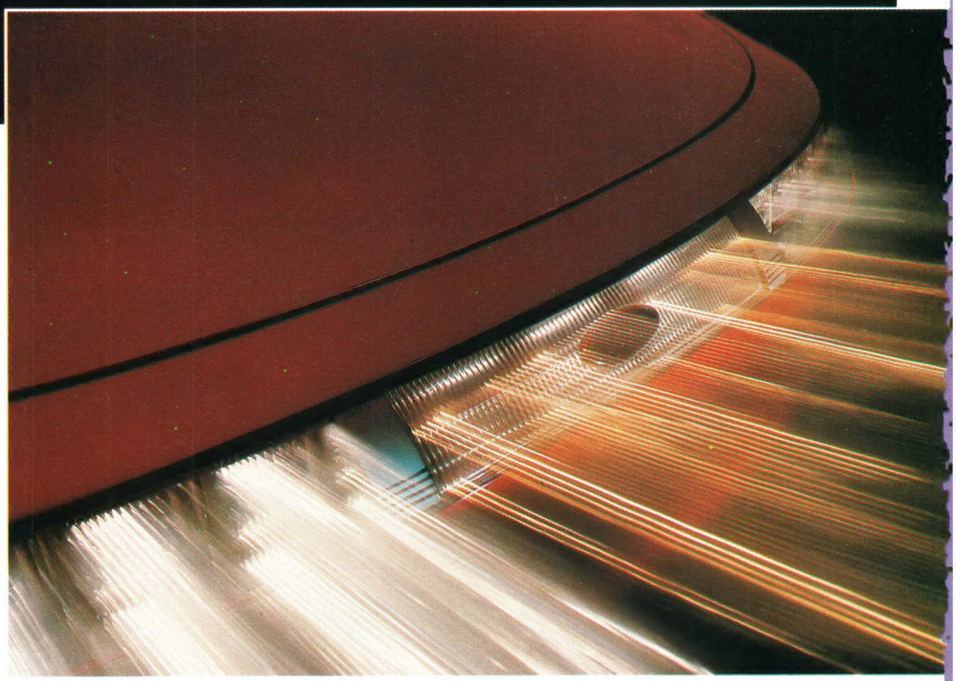
Artificial 'weather' in this dome provides escape from English rain at a holiday village. Another controlled environment – Biosphere II – exists in the USA for research purposes.


Sealand Aerial Photography

SPEEDING AHEAD



Ford



- EASY COMMUTING
- TOMORROW'S CARS
- SUPER-TRAINS

AS ROADS BECOME MORE and more crowded and travelling becomes more of a strain, the major car manufacturers are updating their models with the emphasis on taking the stress out of driving; prototype models of the car of tomorrow are already in existence.

Visually, the most obvious change in the body construction of future cars will be a total lack of seams. Windshields may curve over the driver's head while the rear window will merge with the body, eliminating gaps and ridges that can create turbulence and wind noise.

The major changes, however, will lie under the bonnet, where an integrated electronic system will be used to aid, or replace, many of the present mechanical systems.

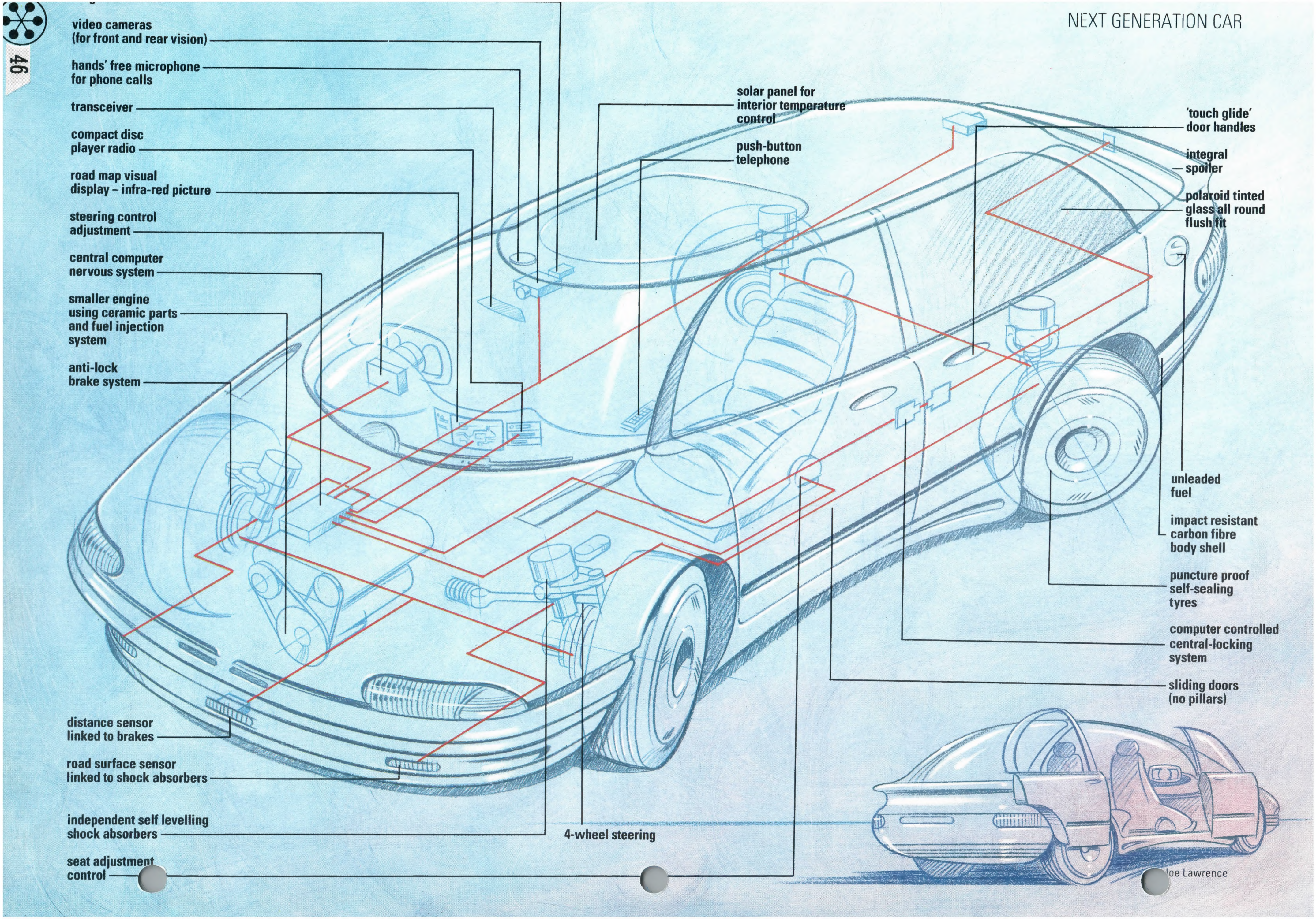
Acting as a powerful integrated electronic nervous system and central brain, it will be capable of:

- automatically unlocking doors, starting the car and the radio, moving seat and steering wheel to preprogrammed preferences
- monitoring the slightest engine malfunction
- measuring the distance between you and the car in front and automatically applying the brakes if the gap narrows dangerously
- responding to potholes or bumps in the road by moving each wheel up and down to compensate for irregularities
- controlling acceleration by sending an electronic signal to the computer to control the throttle.

Safety measures in tomorrow's car will include:

- sensors that will scan blind

***The car of the future** will be lighter, slicker and smaller – indeed, it will be so aerodynamically sleek and efficient, it may even be able to fly. Instead of rolling on tyres, cars might float on a cushion of air, up to 30 cm above the ground. When cars float and friction is no longer a problem, tiny amounts of energy will whisk a vehicle in any direction. When cars have their own power plants to transform sunlight into energy, petrol engines could become obsolete.*


video cameras (for front and rear vision)
hands' free microphone for phone calls
transceiver
compact disc player radio
road map visual display – infra-red picture
steering control adjustment
central computer nervous system
smaller engine using ceramic parts and fuel injection system
anti-lock brake system
distance sensor linked to brakes
road surface sensor linked to shock absorbers
independent self levelling shock absorbers
seat adjustment control
solar panel for interior temperature control
push-button telephone
4-wheel steering
'touch glide' door handles
integral spoiler
polaroid tinted glass all round flush fit
unleaded fuel
impact resistant carbon fibre body shell
puncture proof self-sealing tyres
computer controlled central-locking system
sliding doors (no pillars)
Joe Lawrence

Ford

Ford's prototype Probe V *is more aerodynamic than the F-15 jet plane. The glass roof is sculpted into the body and an electro-optical system replaces mirrors.*

spots for possible dangers

- a dashboard display that will show an infra-red picture of the road ahead to enhance vision at night or in foggy conditions
- increased use of antilock brakes and electronic traction control.

Modern engines

Future models will still be powered by internal-combustion engines, but in a more sophisticated version than anything in use today. The hottest engine parts will be made of ceramics or new metal alloys now being tested.

Most cars will use computer control fuel injection systems instead of the simple carburettor, which blends air and vaporized petrol before they enter the engine cylinder.

New engines will also be wired up with sensors that track everything from the amount of oxygen in the exhaust to vibrations in each cylinder.

Tomorrow's trains

Only 20 years ago, it was being claimed that long-distance train services would shrink to insignificance in the face of competition from road and air transport. But today, a new generation of super-railways is being built in Europe and Japan that will carry passengers at 300 km/h.

In 1955, the first world rail speed record of more than 300 km/h was set by a specially modified French train. But setting records is very far from establishing regular services at such speeds. That requires, quite apart from powerful locomotives:

- the straightest possible track and banked curves, or difficult and costly adaptations of the trains to enable them to corner fast – such as tilting carriages
- the fewest possible tunnels – or else airtight locomotives and carriages, so that passengers will not be disturbed by sudden sharp changes in air pressure
- advanced signalling, to give drivers more warning of when to slow down
- stronger, heavier rails.

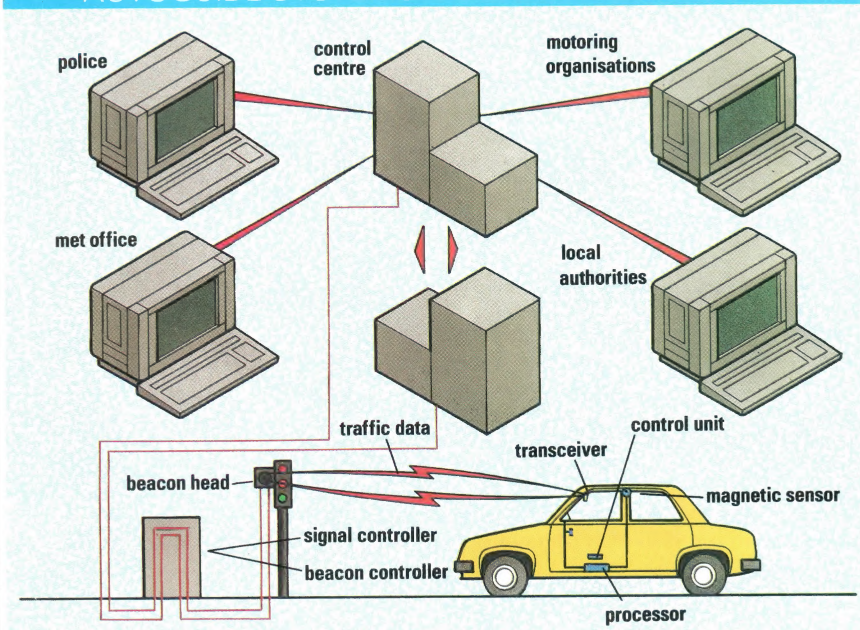
Tracks and trenches

All the super-trains running today and those planned for tomorrow are powered by electricity drawn from overhead lines. The French high-speed trains, called TGVs (*Trains à Grand Vitesse*) have two power cars, one at each end.

The TGVs require their own specially built straight track. The track climbs hills rather than going round them – the trains are powerful enough to be able to cope with gradients of up to 3.5 per cent. Onboard sensors detect a slope and adjust the power accordingly.

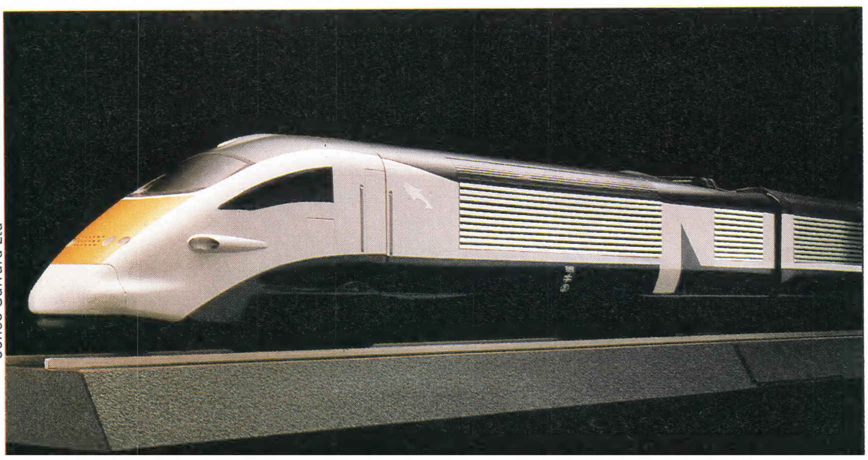
There were no tunnels on the first TGV routes in south-eastern France, because of worries about the

AUTOGUIDE SYSTEMS: FOLLOW THE BEACONS



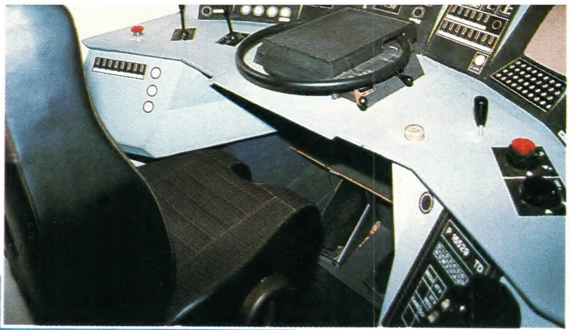
Mark Franklin

Beacons situated at strategic points relay information to cars fitted with two visual display units plus an infra-red receiver and transmitter that are both linked to a central computer. The driver keys in the map reference for his destination. As the car passes each beacon, detailed directions appear on the screen and a synthesized voice issues instructions. Each beacon recognizes where the car wants to go and directs it to the next relevant beacon for further instructions. The system is interactive.



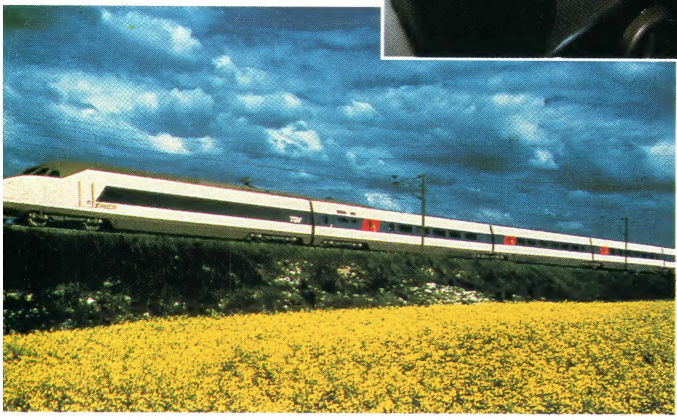
Jones Garrard Ltd

This super train, *destined to carry passengers from a terminal in London to Paris via the Channel Tunnel will reach speeds of 160 km/h through south-east England. At the tunnel terminal it will plunge underground and maintain this speed during its 35 minute crossing.*



French Railways

Electronic signals *displayed inside the cab of the TGV, telling the driver what his speed should be, come from a single control centre at Lyon. There is also a radio telephone link.*



French Railways

The French TGV *came into operation in 1981 and uses its own specially built track that no other trains can operate on. The line was built with as few curves as possible so constant speeds can be maintained. The train is powered by electricity – a pantogragh receives an electric current from overhead wires.*

effects of a train slamming into a mass of air inside the tunnel that could not escape fast enough. So in some places the track had to pass through huge trenches instead.

The great race

In 1965, the famous Japanese 'bullet trains' were first to provide regular services at average speeds above 160km/h, with a maximum of 210 km/h in some places. Today, they touch 270km/h on some routes. A new type called the Series 300 was introduced in March 1992. It has a smaller cross-section to cut air resistance, and numerous other technical improvements, including lightweight aluminium construction. These boost its maximum speed to the 300km/h signified by its name.

In 1989, France opened the first section of a new rail network called *TGV-Atlantique* in western France. Trains on this network were the first able to carry passengers at up to 300km/h. Speeds of up to 270 km/h are reached in some tunnels.

In Germany, a new type of electric train called ICE (Inter-City Express) is capable of 300 km/h. But for safety, they operate only at 270km/h, and only on certain stretches of track. Adjacent tracks are more widely spaced than normal, to give the trains more room to pass each other in tunnels.

In Australia a VFT (Very Fast Train) is proposed, with a maximum speed of 350 km/h. The travel time from Sydney to Melbourne, over 850 km, would be cut to just three hours.

The imminent opening of the Channel Tunnel has prompted British plans too. Proposed trains would consist of 14 cars. At each end there would be a Super-Electra locomotive, developed from British Rail's new Electras. Each would deliver 5,000 kW of power and would be able to work from any of the very varied types of electrical supply used in France, Belgium, the Netherlands and Germany.

Deutsche Bundesbahn

The German ICE *is capable of speeds up to 300 km/h – but this is restricted, in the interests of safety, to a top speed of 270 km/h. Germany is also concentrating on mag-lev trains, which run on a magnetic cushion, and intends to build a high-speed mag-lev line between the towns of Hamburg and Hanover.*

BREAKING RECORDS

On 28 March 1955, a French train hurtled along a stretch of track at more than 300 km/h, breaking the world speed record. But one of its pantographs – a metal framework taking power from overhead power lines – melted in the enormous frictional heat. Next day another train recorded 331 km/h, and lost a pantograph at the same spot.

The 'bullet train' *of Japan – the first high-speed train to provide regular services – has been updated so that it can reach a top speed of 300km/h.*

Tony Stone Photo Library, London

Just amazing!

SUPER JAM

IF ALL THE CARS IN THE WORLD JOINED THE SAME TRAFFIC JAM, IT WOULD CIRCLE THE EARTH 34 TIMES.

Paul Raymonde

ELECTRONIC BRAIN

MEMORY CHIPS

TALKING COMPUTERS

EXPERT SYSTEMS

AN ELECTRONIC REPLICA OF the human brain may be built sometime next century. It may even become possible to transfer everything stored in a human brain to an electronic one.

This would mean that, centuries after the body had perished, a person could continue thinking and, with suitable equipment connected, doing useful work.

Just as the human brain communicates with the outside world through the senses for input, and through speech and movement for output, so an electronic brain – a computer – must be linked to input and output devices if it is to be of use.

Most computers are already linked to standard input and output devices – a keyboard and a screen – but the computer is an ideal 'brain' for a wide range of other electronic and mechanical devices. These provide the computer with 'senses' to receive information from the outside world and with the means to carry out some action in response to the information received.

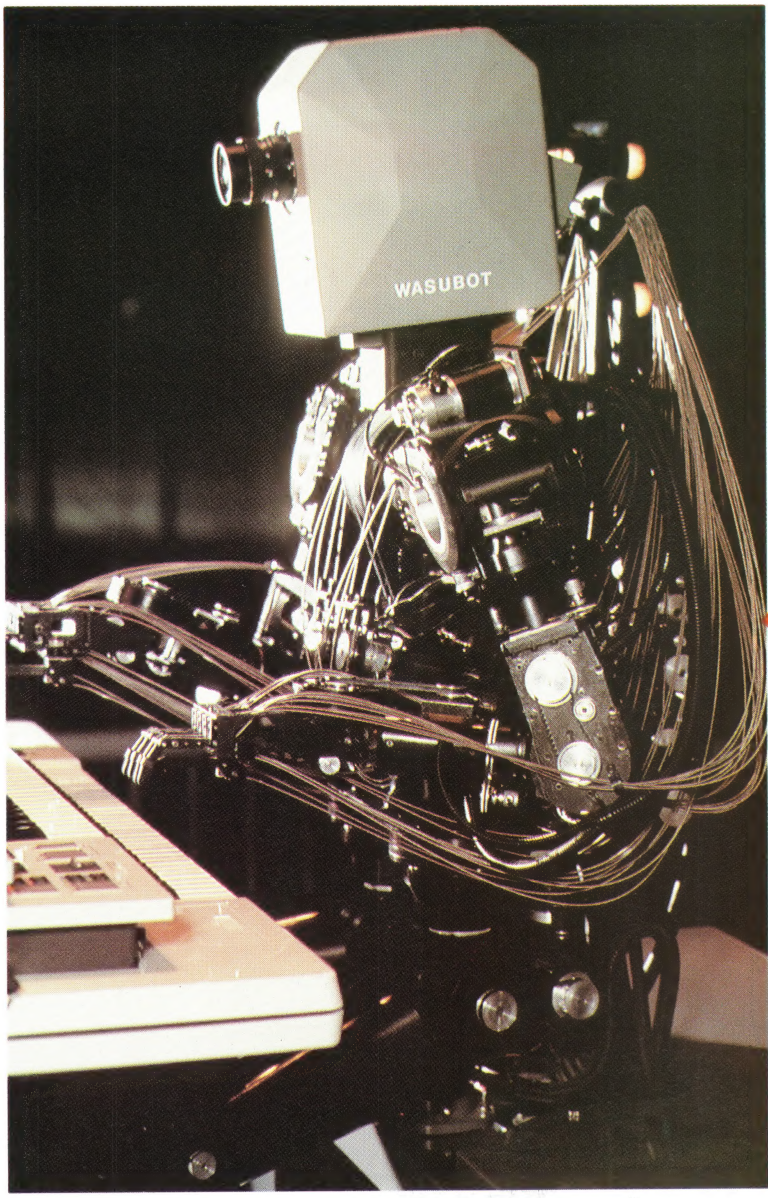
Programming

Before it can do anything useful, a set of instructions called a program has to be fed into the computer. This tells the computer everything it needs to know in order to carry out a particular task.

Most computer programs are stored as a series of magnetic pulses on an iron-oxide-coated tape or disk. A tape or disk unit connected to the computer converts the magnetic pulses into electrical pulses. These are stored in the computer in tiny integrated circuits called memory chips. With a program thus installed, the computer can accept signals from an input device and respond to them by operating an output device. This whole process is controlled by another kind of chip called a microprocessor.

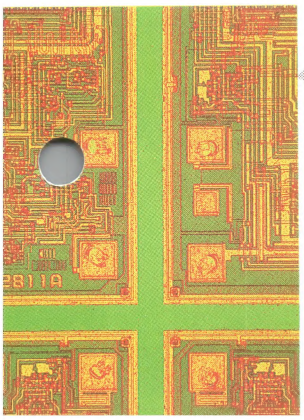
If suitable programs and appropriate input and output devices are available, the computer can carry out a wide range of tasks. With a keyboard and printer, the computer becomes a word processor. With an amplifier and loudspeaker connected, it can act as a music synthesizer. Linked to a mobile vacuum cleaner, you could have a robot that cleans the carpet.

In all of these applications,



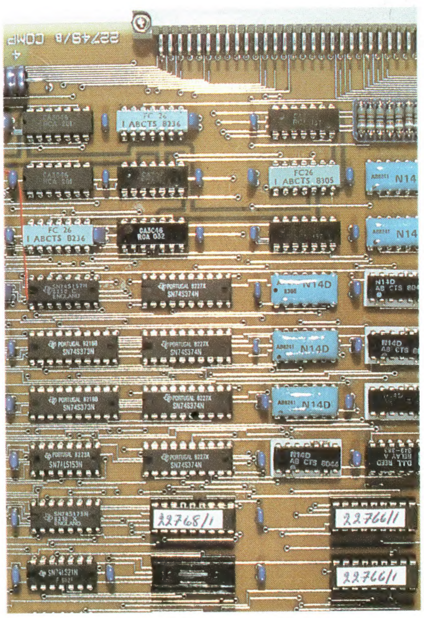
Charlie Cole/Colorific!

***A humanoid robot** plays music on a keyboard – a task involving high-precision computer control and engineering. Something the modern robot is well equipped with.*



David Parker/SPL

***Memory chips** (enlarged) on a silicon crystal before being encapsulated in plastic.*



J A Wall/SPL

***Circuit board** of a computer with encapsulated chips (integrated circuits) soldered in position.*

the computer can be said to act as an electronic brain. In some ways, the computer can easily outperform the human brain. For example, it can work out long mathematical problems rapidly – and with a guarantee of accuracy.

Unlike a person, a computer does not normally forget information that it has been given, no matter how much of it there is. The computer can also work on problems non-stop for weeks, months, or even years. However, some tasks that are extremely easy for people to perform prove much more difficult for the computer.

Pattern matching

One such task is that of recognizing objects. In a manufacturing process, for example, a computer may have to recognize the component parts of an item and make a robot sort them into piles. Recognizing a shape is more difficult than might be expected. A TV camera pointed at the object will produce an image that the computer can compare with patterns stored in its memory. When it finds a matching pattern, the computer 'knows' what object the camera is looking at and can make the robot pick it up and place it in the right pile.

However, even a flat, oblong-shaped part will not be recognized until its image is rotated to match the one stored in the computer memory. This is not difficult to do, but it does slow down the recognition process.

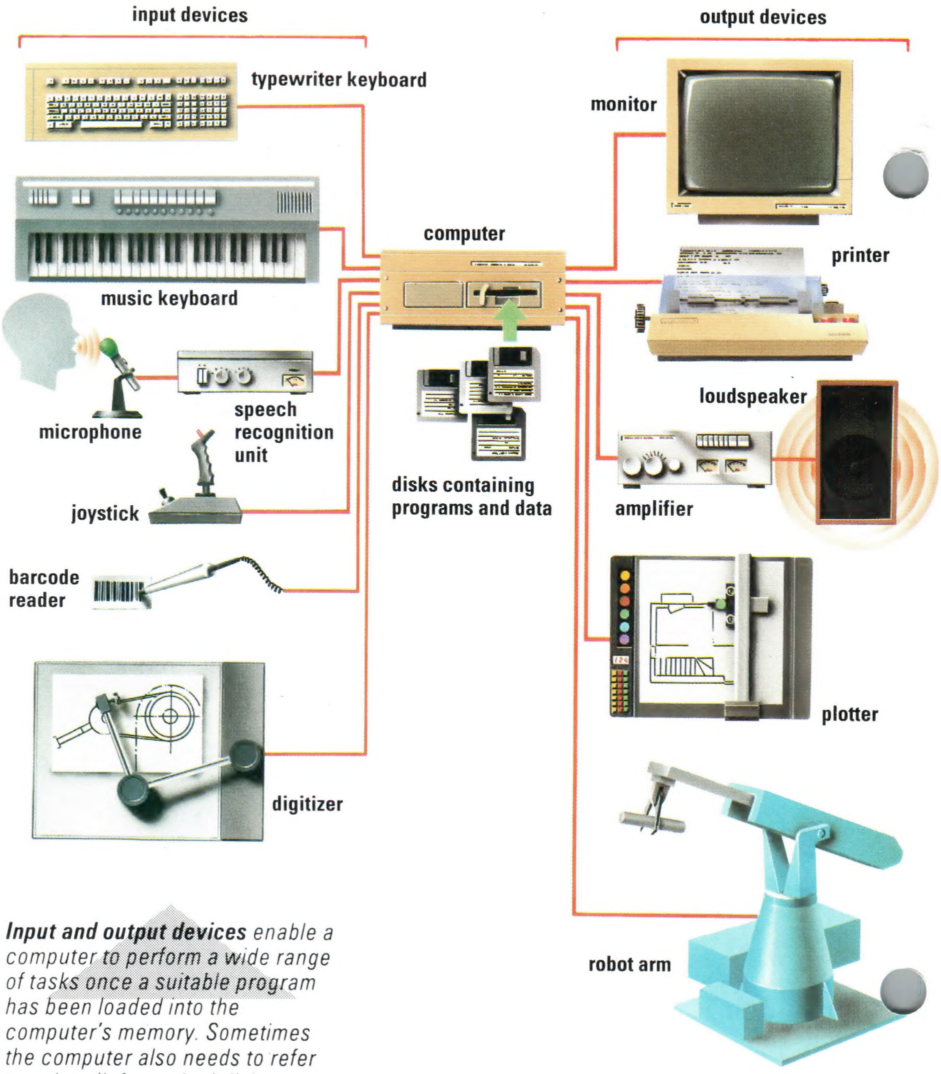
Three-dimensional objects take even longer for the computer to recognize if it is possible for them to appear before the camera any way up and at any angle. Also, the average time taken to identify a part will depend on how many patterns the computer has to compare with the TV image.

By comparison, our brain performs amazingly well. In most cases, we have only to glance at an object to recognize it in a tiny fraction of a second. It could be any one of thousands of objects, at any angle and at any reasonable distance.

Even frogs, which have very simple brains, are extremely quick in recognizing the flies that they feed on, regardless of the angle from which they see them. Many computer scientists are irritated to find that these simple creatures can beat their multi-million pound supercomputers at such tasks. However, this fact may eventually lead someone to discover more effective pattern recognition techniques for use in computers.

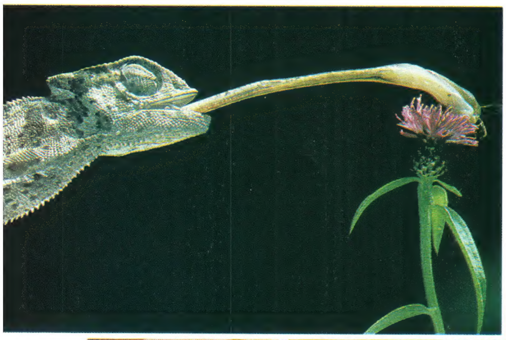
Speech recognition

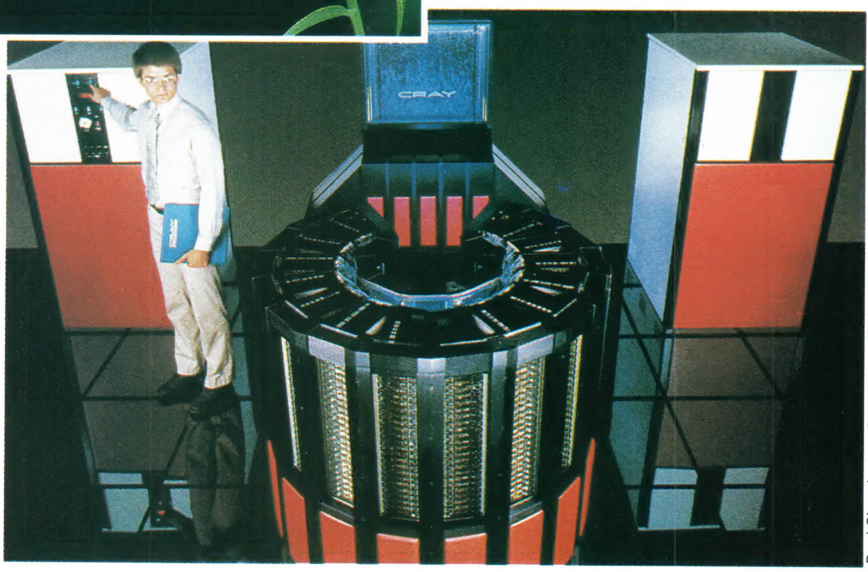
People often control their computers by using a keyboard. For example, when using a games program,



Janos Marffy

Input and output devices *enable a computer to perform a wide range of tasks once a suitable program has been loaded into the computer's memory. Sometimes the computer also needs to refer to a data (information) disk.*


Stephen Dalton/NHPA

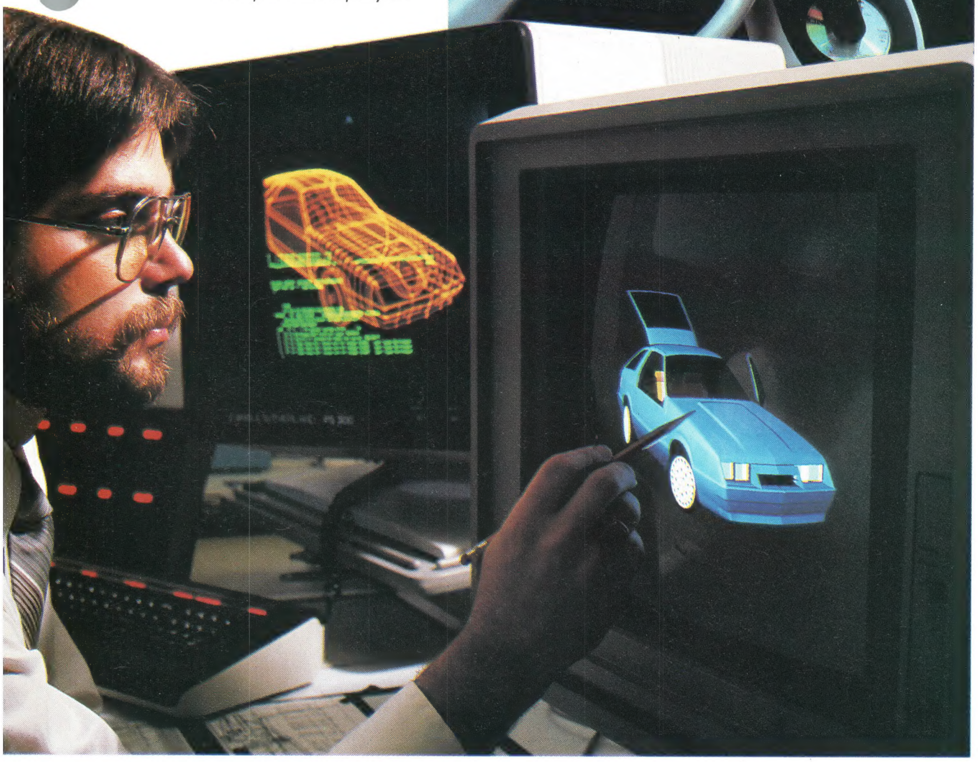


Paul Shambroom/Cray Research Inc

The $20 million Cray 2 *supercomputer, running 250 times as fast as a home computer, is still not fast enough to compete with the chameleon when it comes to catching a fly. By the time the computer had identified a TV image of the fly and extended a robot arm to grab it, the fly would probably have moved off or flown away altogether.*

In-car computers *use signals from the engine and accessories to display data on a screen. This shows journey time, fuel consumption and even what can be heard on the compact disc player.*

George Hayling/SPL



Car shapes *and body finishes can be created on a computer screen with the aid of graphics software. Instead of spraying real cars, various colour schemes can be tried out quickly on the screen.*

Tony Stone Photo Library, London

pressing a single key may fire a gun or move an object across the computer screen. An alternative method is to use spoken commands to communicate with the computer. A microphone picks up the sounds and converts them into electrical signals. These are fed into a speech recognition unit, which is connected to the computer. The unit recognizes the spoken commands and controls the computer accordingly.

This is sometimes done in situations where it is inconvenient for a person to have to type commands in on the computer keyboard. For example, in a factory, a computer might control equipment for lifting heavy objects and moving them to another position. The person controlling the operation may need their hands free for other tasks, or may not be able to stay near the keyboard.

Teaching the computer

In such cases, it is much more convenient to program the computer to understand simple spoken commands, such as 'right', 'left', 'up', 'down', 'forward' and 'back'. On recognizing such a command, the computer sends out signals to control electric motors in the machinery, thus making it carry out the required action.

Even a simple speech recognition task such as this would require a great deal of computer power if the system had to respond to the words regardless of the accent in which they were spoken.

For this reason, many speech recognition systems require the user to teach the computer what the words will sound like. Each word to be recognized has to be spoken several times into a microphone. The computer stores each speech pattern in its memory so that, when a command is spoken, the computer can compare this speech pattern with those stored in its memory. If the computer finds that the command closely matches that of one of the stored patterns, then it will respond to the command and send out the appropriate control signals to the machinery.

Computers able to recognize words spoken in a variety of accents need to be much more powerful. Such machines are used by some companies to connect telephone callers to the correct extension whether they ask for it by number or by the name of the person or department that they want.

Syntax

For more elaborate enquiries, callers would have to ask to talk to a human operator, for a computer simply could not cope. Even if it could recognize a vast range of words, spoken in any accent, there is an even greater problem to solve – syntax. This refers to the way that words are arranged in order to make sense.

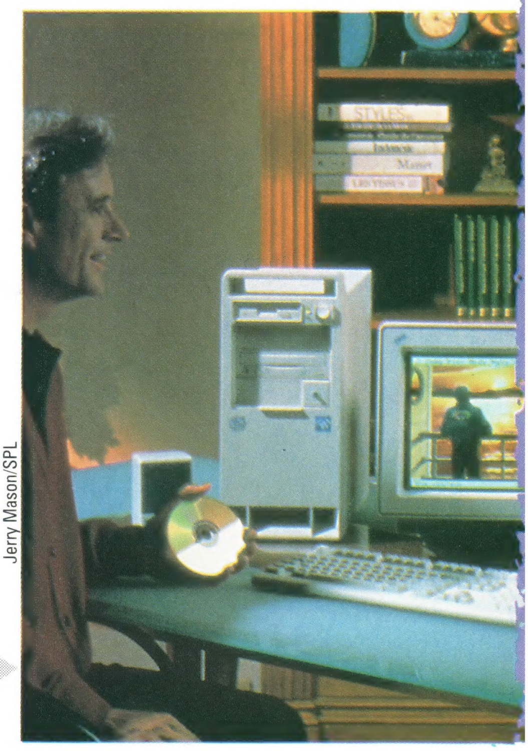
Some words with quite different meanings sound the same when spoken. So it is only by considering the structure of the phrases, clauses or sentences containing

Just amazing!

PHONEY OPERATORS

SOME COMPANIES HAVE COMPUTERS THAT ANSWER THE TELEPHONE, ASK WHO YOU WANT TO SPEAK TO AND CONNECT YOU TO THE RIGHT EXTENSION. THEY WILL EVEN TAKE A MESSAGE IF THE PERSON YOU WANT IS NOT AVAILABLE.

Paul Raymonde



Composing music *is simple when a suitable program is loaded into a home computer. The pitch, quality and duration of the notes are controlled from the computer keyboard.*

Jerry Mason/SPL

Today Rex Features Ltd

Music synthesizers *and sequencers now play a major role in most pop music performances. The synthesizer is a kind of computer designed for generating sounds electronically. The sequencer memorizes sequences of notes and plays them back.*

Speak and Spell *is a computer that teaches children how to spell. The computer speaks a word and the child tries to spell it out on the keyboard. The computer then tells the child whether the spelling is right or wrong.*

Texas Instruments

them that we – or computers – can decide what such words mean. Some progress has been made in getting computers to solve this problem, but it will be some time before they will match the human brain when it comes to recognizing speech.

Computerized sounds

Once a computer has received a spoken command or request, it can easily be made to talk back. It may say that it does not understand what you have said and ask you to repeat the words. Or it may tell you that your message is understood and that it is taking appropriate action – connecting your phone call, controlling a robot or doing whatever else you asked.

Computers form speech sounds using devices called speech synthesizers. These use memory chips to store sounds as electrical signals. Some units can build up any complex word from several separate sounds. Other types store whole words or sentences and usually sound much more realistic. However, they may have a much more limited vocabulary.

Computers can also produce musical sounds. Programs are available to turn home computers into simple music synthesizers so that you can compose, store and replay tunes on them. Some systems will even provide you with a printout of the music you have composed.

Like the brain, a computer receives and stores information, makes decisions based on logic and produces answers to problems. In any task it does, a computer seems to demonstrate that it is a machine with artificial intelligence. Some computers seem remarkably intelligent when carrying out a complex task.

Dan McCoy/Black Star/Colorific!

Chess-playing *computers usually display the game on a screen, but this one uses a robot arm to move real chess pieces.*

ZEFA

Diagnosis *is one area in which computerized expert systems are playing an important role. Information from an x-ray scan is analysed by the computer, which then indicates the nature of the patient's illness.*

Jerrican

Sittler/Jerrican

***Customers** with a plastic card can draw cash from their bank machine at any time of day or night in many countries.*

SMART MONEY

- CASH DISPENSERS
- SECRET NUMBERS
- MICROCHIP CONTROL

MANY PEOPLE WILL SOON carry a tiny computer with them wherever they go. This will be embedded in a plastic 'smart card', which will replace the various plastic cards that people now use to get money from their bank accounts or to pay for goods and services.

These cards act as charge cards, credit cards and cash cards. Plastic cards are issued by various organizations, such as banks, credit card companies and large stores. But, no matter who issues them, they are all the same size and, except for the smart cards, have the same basic features.

The standard credit card or cash card is 86 mm wide, 54 mm high and less than 1 mm thick, with the customer's name and account number embossed on the front. On the back, there is a space where the customer has to write his or her signature, plus a dark, narrow stripe of magnetic material.

This stripe (similar to the surface of recording tape) carries recorded data, such as the customer's account number, that can be read by machine. This stripe has three tracks which, together, can hold up to 226 letters and numbers.

Charge and credit cards

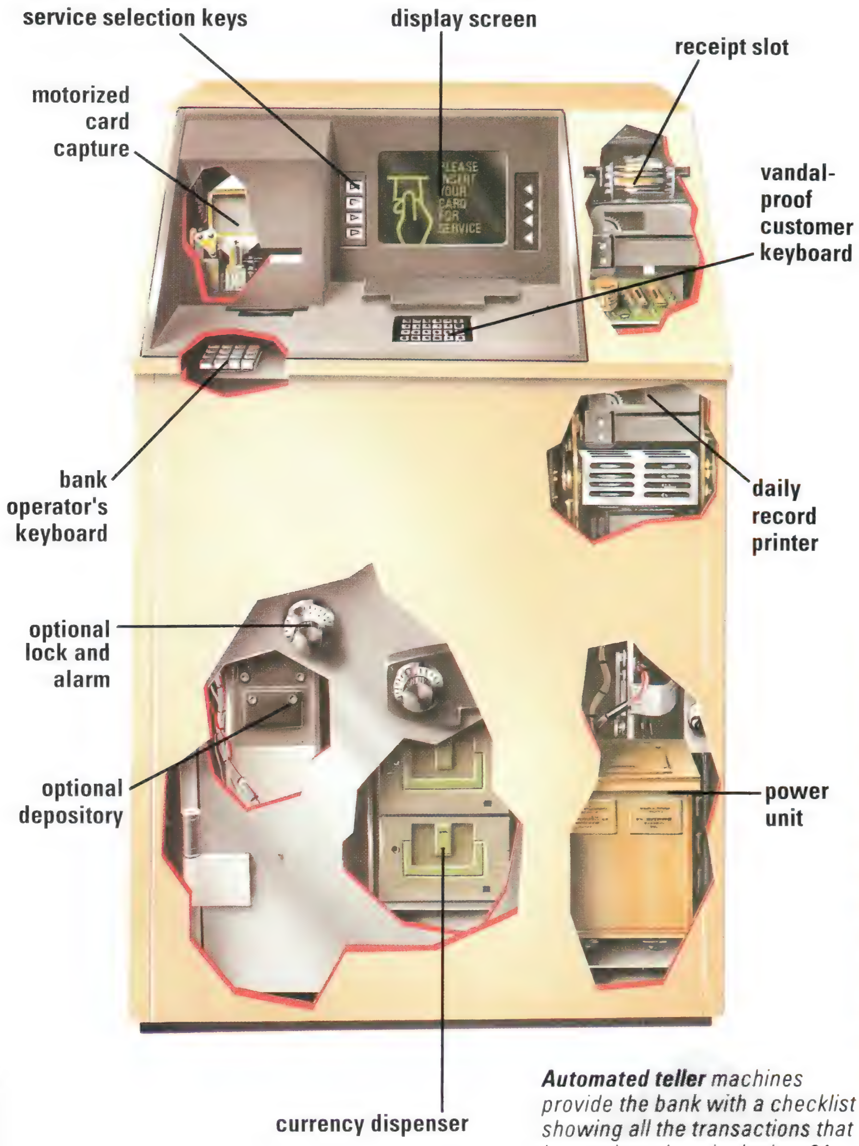
Charge cards, such as those issued by Diners Club and American Express (Amex), and credit cards, such as Access and Visa, were the first types of plastic card to be introduced.

When you buy something with a charge or credit card, the card company pays the shop for what you have bought, then sends you a bill. With a charge card you have to pay the full amount straight away. With a credit card, however, you can pay in monthly instalments. The credit card company tells you what your minimum monthly payment should be and charges you interest on the unpaid amount.

Cash cards

Most banks and building societies have networks of card-operated cash dispensing machines from which their customers can get money at any time, day or night. These machines, called automated teller machines (ATMs) are linked by private telephone lines to the central computers of the banks or other organizations that operate them.

To use a cash card, you feed it into a slot in the ATM and then key in your personal identification number (PIN) on the machine's keyboard. The PIN is a 4-digit number – a sort of password that the bank gives you when it issues you with your card.



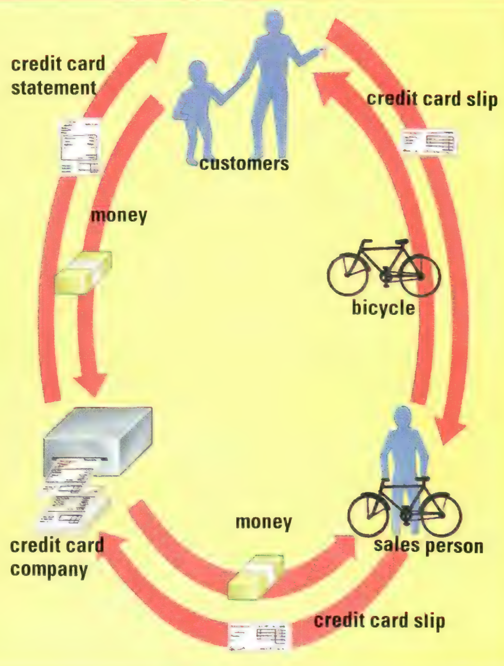
NCR/Janos Marffy

***Automated teller** machines provide the bank with a checklist showing all the transactions that have taken place in the last 24 hours.*

CREDIT PURCHASES – BUY NOW, PAY LATER

When you purchase an item by credit card, the card is usually placed in a small machine that transfers embossed details from the card on to slips of paper. A description of the item and its cost are written on the slips, which the customer then signs.

The salesperson checks that the signature on the slips matches the one on the card to make sure that the person with the card is entitled to use it. The store and the customer each keep a sales slip. The store sends its used slips to the credit card company, which then pays the store the necessary amount, less a small charge for the service. Once a month, a statement is sent to a customer showing what is owed. This can be paid all at once, or in instalments. Interest is charged on any unpaid amount.

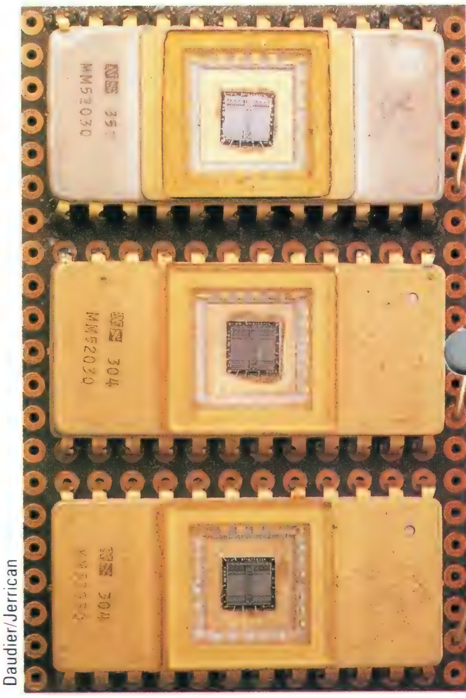


Mark Franklin

The computer checks that the PIN number you key in is the correct one for your account number, which the ATM has read from the magnetic stripe on the back of the card. You will not be able to use the machine unless it is. This is to stop unauthorized use of your card. You are supposed to keep your PIN number secret so that no-one else can use your card if it gets lost or stolen.

If you make a mistake when keying in your PIN number, the machine lets you try again. But if you get it wrong three times, it keeps your card and you have to ask the bank for a new one. The banks assume that, if someone gets the number wrong three times, they are probably an unauthorized user trying to obtain money by using someone else's card.

When you have keyed in the right PIN number, the machine usually gives you a choice of services,



Daudier/Jerrican

***Integrated circuits** (silicon chips) provide the computing power required in today's money dispensing machines.*

which are shown on its display screen. Besides giving you cash, the machine can let you check your bank balance, order a new cheque book or ask for details of your account to be sent to you. You choose the service you want by pressing a button next to the display screen.

To get cash, you select the amount you want on a set of buttons. The machine checks with the computer to see if you have sufficient funds in your account, and whether or not you have exceeded any daily or weekly limit set by the bank on how much can be withdrawn using the card. If all is well, the machine counts out the


Mike Cooper

notes and delivers them through a slot. The central computer automatically deducts the amount from your bank account.

The machine may then ask you if you want to use any of its other services. If you do, it tells the central computer what you want and the computer arranges it for you. If you do not require any other services from the machine, it returns your card.

Flexibility

Many banks that operate ATMs have arrangements with each other so that you can use a cash card issued by one bank in the ATMs of another. Eventually, anyone with a cash card will be able to use it in any ATM. This is already the case in Italy and, by the end of the 1990s, all the ATM systems in Europe will be interlinked.

Just amazing!

WALLET WALLY

THE WORLD'S BIGGEST WALLET, WEIGHING NEARLY 16 KG AND OPENING TO OVER 76 METRES, WAS MADE FOR WALTER CAVANAGH OF CALIFORNIA, TO HOLD HIS 1,196 CREDIT CARDS.

Paul Raymonds

It is also possible to use some credit cards and charge cards to get cash from bank ATMs, using a PIN number issued to you by the card company.

When you do this, the bank's computer tells the credit card company how much money you have had, so that it can be paid back to the bank and charged to your credit card account.

Eftpos

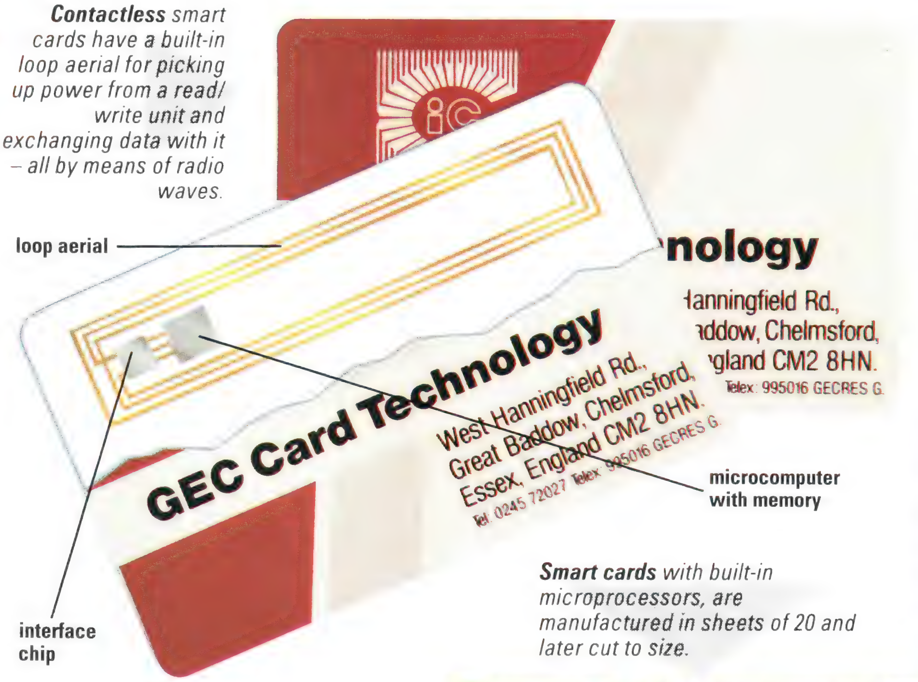
The latest step towards the 'cashless society' is the introduction of Eftpos – Electronic Funds Transfer at the Point Of Sale. This is a huge computer network linking the computer systems of banks and credit card companies with each other and with terminals installed in shops and other places where goods or services are sold.

__Money__ is transferred from your bank account to that of the store after your electronic funds transfer card has been checked via a terminal on the counter.

With the Eftpos system, you can buy things using either a specially-issued card called a debit card, or your existing cash card, credit card or cheque guarantee card. The shop assistant enters the details of your purchases on the Eftpos terminal the same way as on an ordinary till. Then your card is passed ('wiped') through a slot on the terminal, and you enter your PIN number on a small keyboard.

The terminal calls up your bank or credit card company computer to check that it is all right for the sale to go ahead. If it is, the cost is automatically deducted from your bank account, or charged to your credit card account, and paid into the shop's bank account.

__Contactless__ smart cards have a built-in loop aerial for picking up power from a read/write unit and exchanging data with it – all by means of radio waves.



Ray Duns

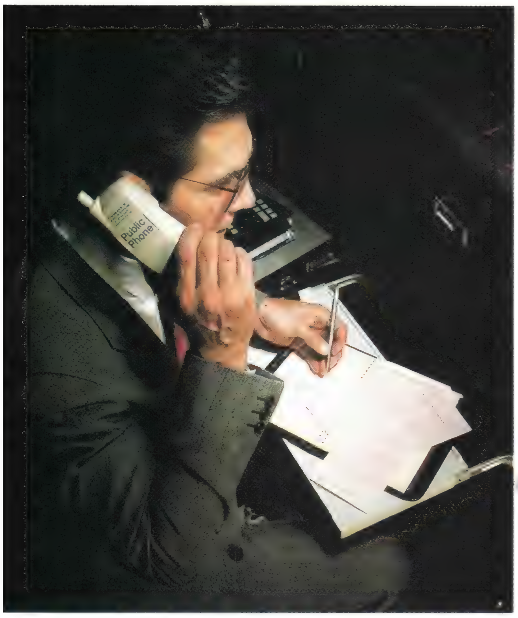
__Smart cards__ with built-in microprocessors, are manufactured in sheets of 20 and later cut to size.

TELEPHONE CARDS

One of the simplest substitutes for cash is the Phonecard, which can be used in many public telephones. Phonecards of various values can be purchased in Post Offices, newsagents and other shops in the UK. Their value is recorded on a magnetic coating on the back. Before making a call, the card is inserted in the telephone equipment. This automatically reads the value of the card and deducts from it the cost of the call. You can use the card for calls until the amount you paid for it has been used up.

An alternative to the Phonecard is the telephone credit card. The telephone company's computer records your card number and the cost of each call that you make. You are sent a bill every three months.


Pitchal/Jerrican



GTE Airfone Incorporated

***Telephoning** from an aircraft is now possible on some routes. Payment is made by inserting a credit card in a slot, rather than coins which would be inconvenient on international flights with passengers holding various currencies.*

The 'smart' card is a new type of card that will eventually replace all our existing ones. The smart card is exactly the same size as a credit card, but has a microprocessor and memory circuits built into it. This enables the card to carry far more data than can be held on the magnetic stripes of ordinary cards.

Multi-purpose

A single smart card can, therefore, be used for many purposes – as a credit card, a cash card or a telephone payment card. It could even be used as an electronic identity card, club membership card or passport.

The first smart cards to be developed are already widely used in France and other countries. These cards have a set of contacts along one edge and can be plugged into cash dispensers, payphones or other terminals. However, the contacts sometimes get damaged or dirty, preventing correct operation, so contactless cards have been developed more recently.

The contactless card, invented in England by GEC, contains loops of wire that act like a radio aerial. In use, the card is placed on top of a read/write unit, a flat plate on the cash dispenser or other terminal. Radio waves generated by this unit are picked up by the loops in the card and are used to provide the electricity to power the card's microprocessor and memory. The transfer of data to and from the card is also by radio.

The smart card can be used just like a debit or credit card to buy things. But it can also be used like cash. Using a special bank terminal, you can load the card's memory with 'money' from your bank account and use it to buy small items, such as sweets or magazines. A read/write unit in the shop will deduct the cost of what you buy from the money stored in the card's memory and store the new balance on the card.

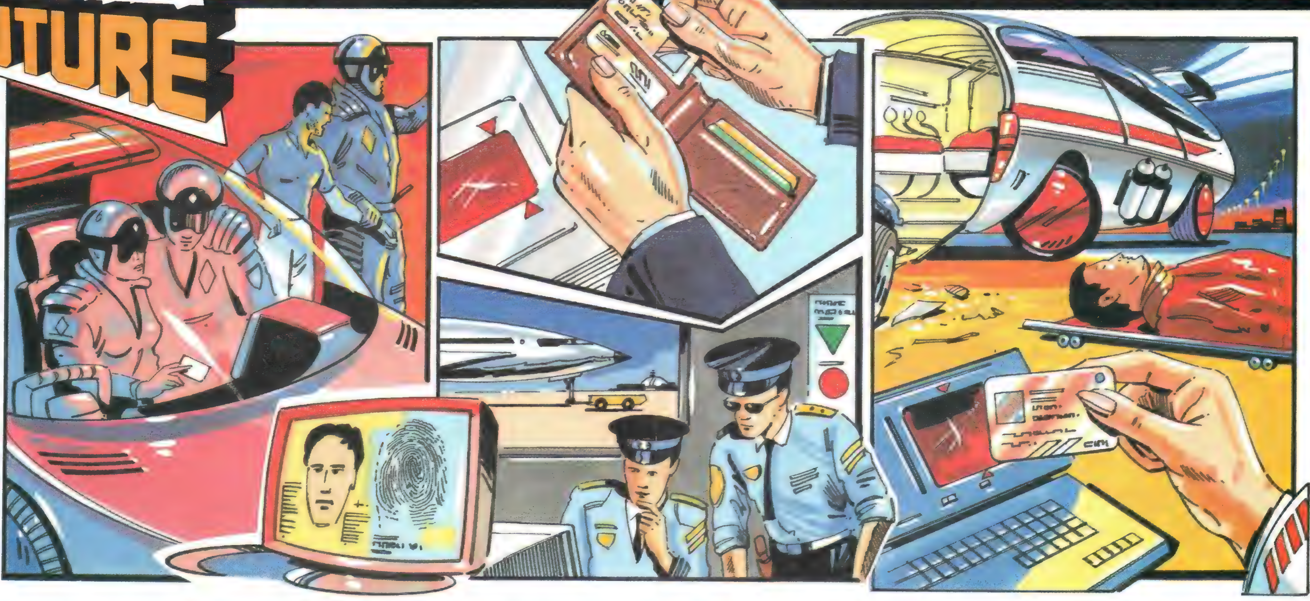
Visa International-EMEA Region

***Similar** to an ordinary credit card from the front, the back of this smart card has electrical contacts, a tiny display screen and even a keyboard.*

At the moment, smart cards are used with PIN numbers to guard against fraud. But alternative security systems are being developed and, in years to come, the card read/write unit may check your identity by examining your fingerprints or, even more simply, by checking the pattern of blood vessels in your fingertips.

INTO THE FUTURE

ON THE CARDS



Joe Lawrence

▲ Besides taking care of your financial transactions, a smart card may act as an identity card, containing records of your fingerprints (and any convictions).

▲ The card would also act as a passport, with any necessary visas added before departure, and dates of entry and exit added by border officials.

▲ In case of accident, doctors could use your smart card to check your medical record. This would include details of any treatment required for existing problems.

MICRO IMAGES

Mike Goldwater/Network Photographers

Business Imaging Systems/Kodak Ltd

- POCKET LIBRARIES
- ATOMIC WRITING
- OPTICAL ID

STORING INFORMATION AS images is as old as human communication itself. Today, these images are stored on the printed page and microfilm, and in digital form in computer memories, on magnetic media, optical cards and discs.

In the future, ever larger amounts of information will be stored in ever smaller spaces – perhaps even on atoms themselves.

Storing information using light is being done by British Telecom and a London hospital. They are using a small plastic card, coated on one side with shiny metal, to store patients' medical records. A complete set of records can be stored this way – the card holds the equivalent of up to 800 sides of standard A4 paper covered with text – and the patient can carry their medical ID card around with them.

The information is digitized and burnt into the surface of the card by a small laser in 2,500 rows of small holes. To read the card, another (less powerful) laser sweeps the surface and the variations in the light reflected – caused by the holes – is picked up by a sensor. Both the laser recorder and reader are housed in a drive that can be connected to a personal computer.

TeleFocus

***Complete medical records** can be stored optically on a 'clever' card that patients can carry with them in their wallet.*

***Vast amounts** of information can be stored as digital images on optical discs. The whole of the new Oxford English Dictionary is now contained on just one disc (inset above).*

The information on the card cannot be erased – only added to. There are 2,600 kilobytes available, about three and a half times the data capacity of a personal computer's double density floppy disc.

In future, cards carrying large amounts of data could have many applications. They could carry information about banking, health, identity and could be slipped into write/read slots in banks, at the

Just amazing!

PINHEAD PRAYER

THE LORD'S PRAYER FROM THE CHRISTIAN RELIGION HAS ACTUALLY BEEN ENGRAVED BY HAND ON THE HEAD OF A PIN – AN AREA OF JUST ONE SQUARE MILLIMETRE

Paul Raymonde

doctors' surgery and at other places where you need to make transactions or to have information available on the spot.

They have some competition, however, from the so-called 'smart' cards that have tiny computer memory chips incorporated into them. These can be read and updated. They are also more flexible because, under certain conditions, information can be erased.

Optical discs

Compact discs have been around for a number of years. But the disadvantage of the standard optical CD in computer use is that no new information can be recorded on it once it has been manufactured. However, new optical discs for computers can record information. They are known as WORM discs. WORM stands for Write Once Read Many times.

A powerful laser burns pits in these discs. These pits are then read by a less powerful laser and a detector. IBM sell a 13 cm WORM optical disc which, with the appropriate optical disc drive, can be used with a personal computer. It has a 200 megabyte capacity – about 5 times the capacity of a typical hard disc on a desktop computer.

Erase and re-use

The beauty of this optical disc is that very large amounts of information can be swapped between computers with the ease of swapping data on regular floppy discs. Manufacturers have since produced erasable optical discs where information can be deleted and the disc can then be re-used.

The optical storage of information is very useful as large amounts of text or images can be handled. A new system called CDI is able to store thousands of digitally encoded colour pictures on a single disc. This means that photographic libraries and TV image banks can now consist of discs and disc readers with high-definition screens. Searching for a particular picture takes only seconds.

Tiny images can be made using photographic reduction. This technology is familiar in libraries, bookshops and garages, where microfiche readers and books containing sheets of microfiche material are commonly seen. In a microfiche, or microfilm, pages of printed information are optically reduced and printed on film.

The amount of information a microfiche can contain depends on the size of the photographic grain but, using this technology, approximately two sentences of printed words fit into about one square millimetre. Linear reductions of about 20 diameters are common.

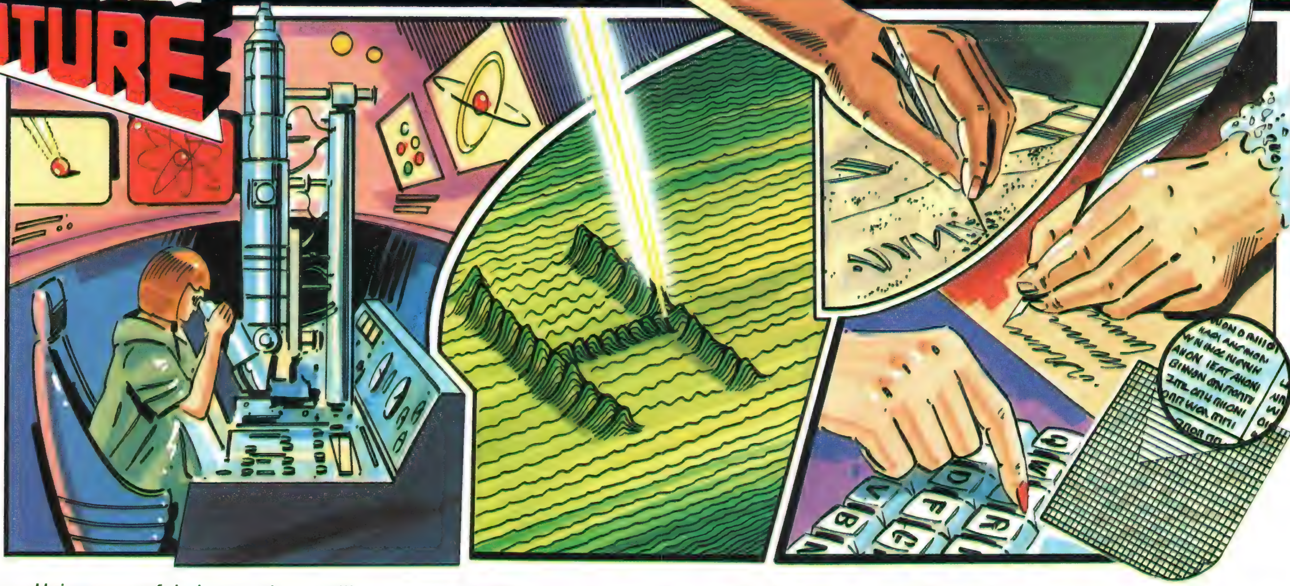
There is a limitation to this technique, however, even if the finest-grain film were used. Reducing and enlarging optical devices have a resolving power limited to that near the wavelength of visible light.

__Microfiche readers__ have replaced card indexes in most libraries. The details of every book can be held on just a few sheets of film.

Peter Aprahamian/SPL

INTO THE FUTURE

ENGRAVING ON ATOMS



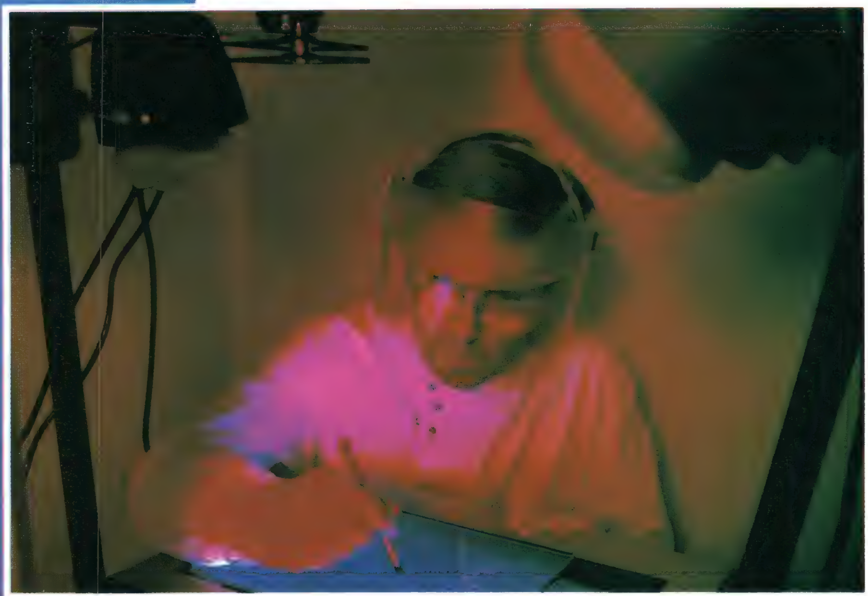
▲ *Using powerful electron beams like those in electron microscopes, researchers can move single atoms on the surface of a material.*

▲ *Ultimately it should be possible to move atoms in ones and twos into the shape of minute letters and form words and sentences.*

▲ *This would mean that you could write every written work ever produced in the history of the world on a piece of paper 3 metres square.*

Joe Lawrence

GENE BANK



M Baret/Rapho/SPL

ICI Agrochemicals

Plant seeds *being identified and separated in a process known as genetic fingerprinting.*

Microinjection *is a technique for introducing other, or more, DNA into a cell via a very fine needle.*

- WILDTYPES
- IMPROVING YIELD
- NEW FRUIT

TROPICAL RAIN FORESTS ARE an enormous reservoir of life forms. They are a storehouse of genes – the 'chemical blueprints' inside each living thing that carry the instructions for building and running that particular species of animal or plant.

Using modern techniques of genetic engineering, scientists can manipulate these genes. As a result, they are always on the look-out for new genes and novel combinations of genes. The aim may be to produce a cow with a better milk yield, a new way of making a life-saving drug, or a new flavour of tomato.

We know next to nothing of the full potential of jungle plants and creatures. It is thought that less than ten per cent of jungle plants have been discovered and recorded: even fewer – about one per cent – have been studied in detail.

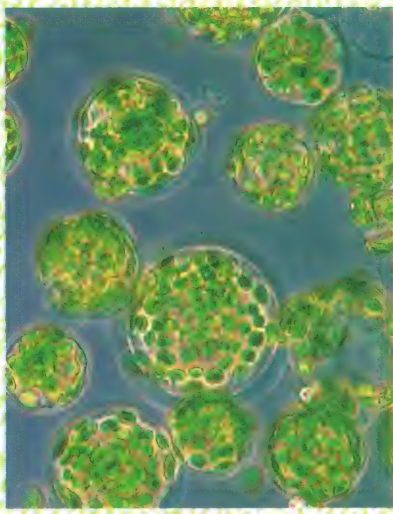
Tropical forests contain a vast genetic diversity because they contain so many species and varieties of species. These include the original 'wildtypes' of some of the plants and animals that have been specially bred to be economically useful to mankind.

WEEDING THE GENES

Many rain forest plants, including tobacco (right), have been improved and made more resistant to diseases and pests by certain genetic engineering techniques.

To start with, the tough fibrous outer walls of the cells are chemically removed. The resulting (intact) cells are called protoplasts and masses of these are grown in dishes filled with a sterile growing medium containing organic materials, vitamins and growth substances as required. Normal healthy plants grow from the protoplast cells. To speed up their growth, a very low electric current is passed through the growing medium.

Cloning cells and the process of accelerated propagation are techniques that are essential to genetic engineering.



Sinclair Stammers/SPL

Christopher Sainsbury/Orpix

A new species *is examined by experts who make a detailed description and compare it with other finds using a classification key – a series of questions about the structure. A new find will be given an international name in Latin.*

These wildtypes may contain additional genes that could be added to our food crops to make them more resistant to disease, or cause them to produce better yields.

Scientists realized how useful the wildtypes could be in the 1920s, when a disease was wiping out sugar cane plantations in South America. The effects of the disease were stopped by crossbreeding the canes with a wildtype cane from the jungles of Java, which was resistant to the disease. The new hybrid canes had the sugar-producing qualities of the old plantation canes and the disease resistance of the wildtype ones.

In 1970, great areas of the USA's cornfields were blighted by fungus, causing losses of $2 billion. The problem was solved by crossbreeding the American corn with a Mexican corn that had genes for resistance to the fungus.

The world's cocoa plantations are descended from a few original plants that grew in the Amazon jungle. They have very limited genetic variation. During the 1980s a search was started in the cacao tree's original jungle home for wildtype varieties of cocoa, which might improve yield and resistance to disease.

New varieties of fruits and other produce are also being created. The mangosteen, a new and succulent fruit from the Malaysian jungle – similar to a lychee – is being marketed all over the world.

The household tomato came originally from tropical Ecuador. By breeding the first strain with different wildtype tomatoes, the fruit has been made more resistant to fungus infection, had its shape changed to be more suitable for mechanical harvesting, had extra vitamin C added, and had its colour made a deeper red. Unfortunately, in the course of these changes much of the flavour has been lost.

Dr Nigel Smith/Hutchison Library

Crossbreeding *the sugar cane on the left, suffering from a disease known as rust, with a wildtype has added a gene that makes the crop resistant to rust.*

Philippe Plailly/SPL

Wheat *is one of the many plants that has benefited from genetic engineering, which has produced a crop that can grow in harsh climates and in poor soil.*

Wild ox

The kouprey is a wild ox from Cambodia. It is thought to be resistant to rinderpest disease, a highly contagious, viral disease which causes huge losses in herds of Western cattle. But the kouprey is rare and hardly ever seen.

Warfare, logging and clearance for crops is threatening its forest home. Only if the Cambodian jungle is preserved will the kouprey increase in numbers, allowing research into its resistant genes.

A simple form of 'genetic engineering' – selecting plants and animals with particular characteristics and breeding them – has been carried out by mankind ever since animals were first herded and the first corn was planted.

Breeding from the cows that gave the most milk and were docile or from the cereals that produced the most grain was the first step to domestication. But it was largely luck whether the desired combination of genes came together.

Today, the techniques of genetic engineering are carried out within cells themselves, under the microscope. An individual gene can be lifted from one cell and inserted into another cell, which may be from a different species. The transfer of genes is done using enzymes and viruses, which 'carry' genes into the cells they infect. The new cell is then made to divide and eventually grows into a new organism.

Genetic engineering is a fairly new technique. Yet, given the vast reserves of genetic material in tropical rain forests, many scientists believe it is potentially very useful.

Just amazing!

SPRING CROP

A GENE FROM A MEXICAN WILDTYPE CORN COULD MAKE A HARVESTABLE CROP GROW FROM PERENNIAL BULBS LIKE DAFFODILS OR TULIPS.

Paul Raymonde

HI-TECH SEX

- EGGS AND SPERM
- EMBRYO FLUSHING
- NUCLEAR TRANSFER

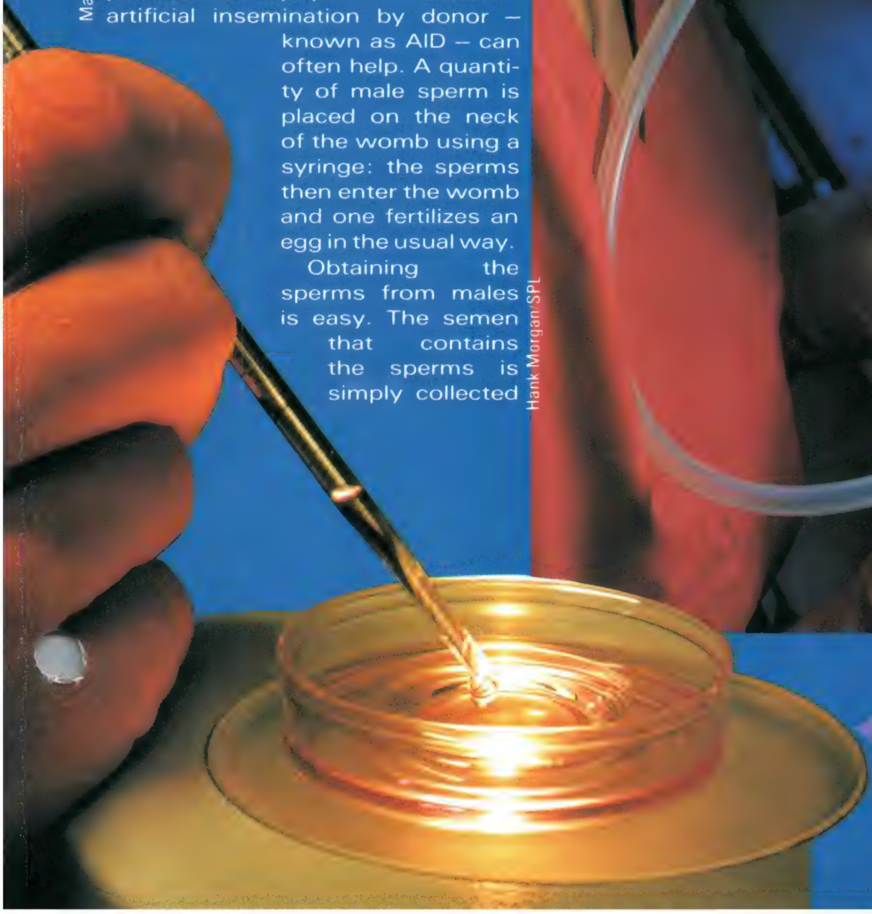
TWO FRAGMENTS OF LIVING matter, the egg and the sperm, are essential for the creation of each new life. So the key to the control of reproduction is the ability to obtain, preserve and handle these elements.

The larger of the fragments is the egg, which is formed inside female mammals. Each human egg is about 0.13 mm across and weighs around a millionth of a gram. The male provides the other fragment, the sperm. This is usually much smaller and lighter than the egg, and millions are produced at a time.

One in eight human couples are unable to have children, a condition known as infertility. This is often caused by the inability of the male to produce healthy sperm. In this case, artificial insemination by donor – known as AID – can often help. A quantity of male sperm is placed on the neck of the womb using a syringe: the sperms then enter the womb and one fertilizes an egg in the usual way.

Obtaining the sperms from males is easy. The semen that contains the sperms is simply collected in glass containers and then tested to make sure that the sperms are active and free from infection. After testing, the semen is mixed with a cryoprotectant – a sterile liquid that freezes below 0°C. This mixture is then slowly cooled to –7°C, just above the temperature at which it freezes.

A laboratory technician then picks up the container of semen using metal forceps cooled in a container of liquid nitrogen. This



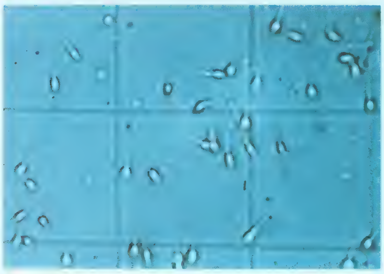
Martin Dohrn/SPL

Hank Morgan/SPL

***In human** in vitro fertilization, a couple of eggs are floated in a glass dish and the sperms are added using a hollow glass tube.*

***Human embryos** are examined to make sure the new life is developing correctly. Only perfect ones are implanted.*

THE SPERM COUNT



Vioujard/Frank Spooner Pictures

If a human couple are infertile, one of the first medical checks is to count the number of sperm being produced. Males usually produce about 350 million sperms at a time: if the number of sperms is below 20 million, it is unlikely that the couple will conceive naturally. But numbers are not enough – the sperms must be active. Propelled by their tails, they should move at a rate of up to 3 mm per minute. If fewer than 40% are active, conception is unlikely so couples with this problem often turn to artificial insemination to have a family.

Petit Format/Nestle/SPL

cools the mixture down further, and does so very quickly. As a result, any ice crystals that form in the cells are very small and so do not damage the cell structure. After this initial quick freeze, the sample is again cooled very slowly, reaching −50°C in three to four hours.

The semen is then placed in a flask of liquid nitrogen for long-term storage at −196°C. Human sperm is stored in sperm banks which are equipped with the necessary freezing equipment.

Unknown donors

The men who provide the sperm – the donors – are only allowed to father 12 children in total by artificial insemination, the names of the donors are not known and only the people involved know how the child was conceived.

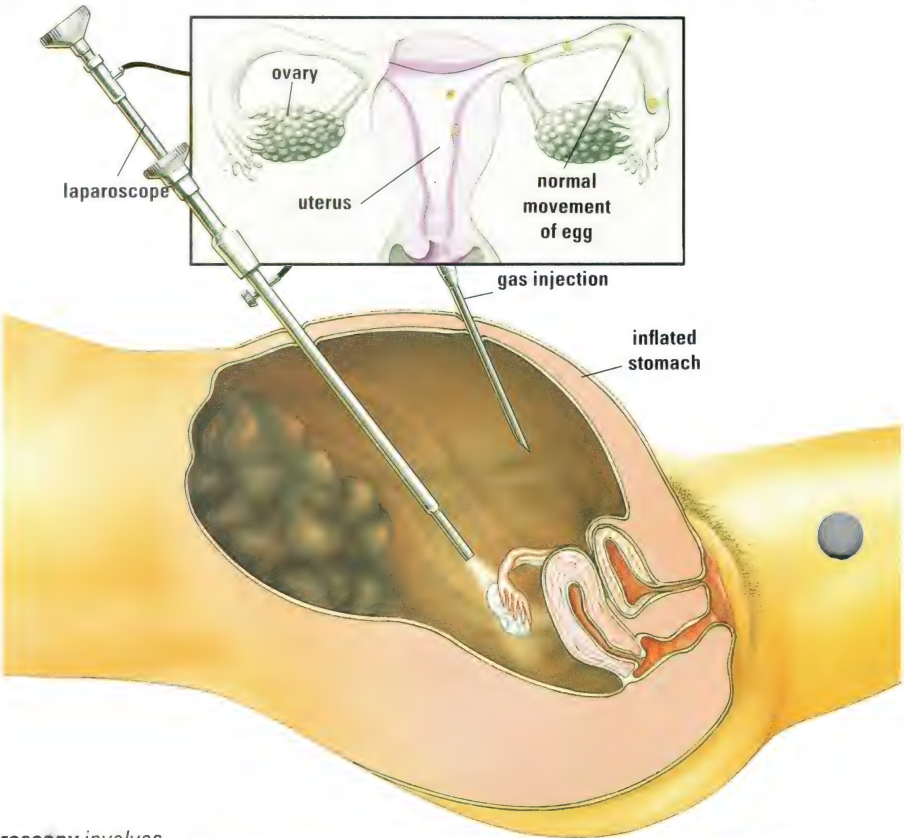
Infertility also occurs if an egg duct – Fallopian tube – is blocked or the female does not produce mature eggs. This can be confirmed by examining the ovaries and fallopian tubes through a surgical instrument called a laparoscope. Many women not producing mature eggs are then treated with hormones to help the eggs mature. These hormones are normally referred to as fertility drugs.

After taking these drugs, most women conceive in the normal way after a few months. But if conception has not occurred after taking fertility drugs for some time and the ovary is definitely producing eggs, another treatment is available.

This process starts off with a ripe egg removed from the female, again using a laparoscope. An egg is simply sucked out of the ripe follicle on the surface of the ovary and removed through the hollow centre of the laparoscope.

The egg and some active sperms are placed in a shallow glass dish. A technician then jockeys the two elements towards each other until a sperm breaks through the outer coat of the egg and fertilization occurs. As it takes place in a glass dish, this is known as *in vitro* (in glass) fertilization.

The fertilized egg is then placed in the womb of the woman who has produced the egg. In 70% of cases, the egg implants successfully in the lining of the womb and a normal human baby is eventually born.



***Laparoscopy** involves inflating the abdomen with harmless gas and inserting a tube through a small cut just below the navel. The laparoscope itself consists of a fibre-optic tube through which the surgeon can see the outside of organs such as the ovaries and the fallopian tube (see photo above left which shows follicle on surface of ovary.*

***Human sperm** is stored for long periods in insulated flasks of liquid nitrogen at −196°C. At this temperature, the containers can only be handled using heavy gloves.*

Douglas Kirkland/C[illegible]tact/Colorific!

Avoncroft Cattle Breeders Ltd

Selected AI bulls *are weighed regularly to make sure that they are in good health and getting enough to eat. Their food consumption is also recorded so that breeders can work out how efficient each bull is at converting food into meat. Many bulls are pure bred, like this Hereford, but cross-breeds are also used.*

Babies conceived in this way are known as 'test tube babies'.

Artificial insemination – AI – is an important part of the farming routine. Livestock have been selectively bred for thousands of years by using only the best males for breeding, but now various organizations collect and store the sperm from selected bulls. In contrast to the unknown human sperm donors, very careful records are kept of the bulls which provide the sperm.

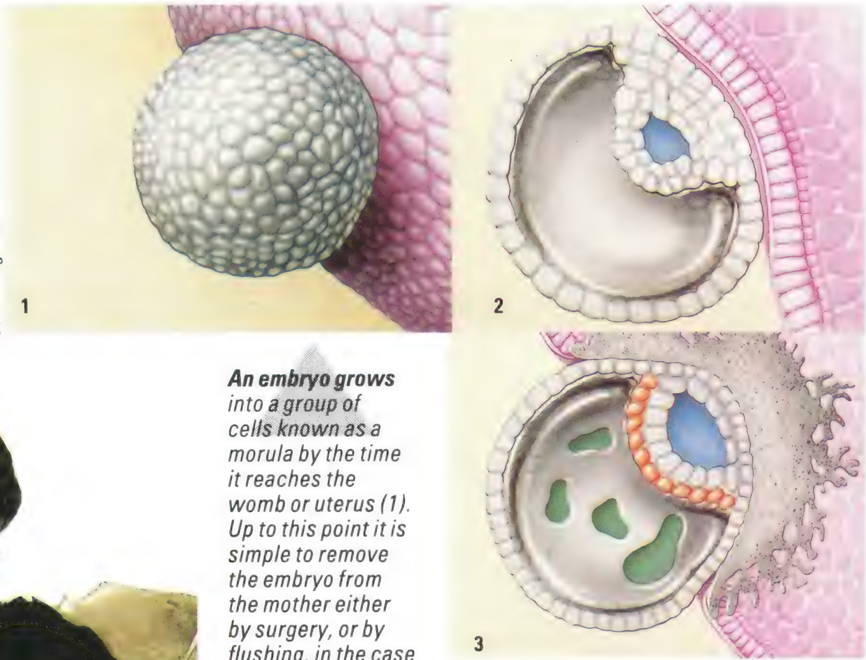
For example, farmers might want to create cows with more meat on them, or to improve their milk yield. These factors are carefully measured, so a farmer can take his or her pick of the most suitable bulls.

Once the choice has been made, a dose of frozen sperm is ordered and a farmer can either place it in the cow himself or ask an AI technician to do the job. The frozen sperm arrives at the farm in a paper straw and is quickly thawed in warm water just before use.

Embryo flushing and implantation is not yet as popular as artificial insemination in livestock breeding, but it is spreading fast.

Cows with a good milking record or similar desirable characteristics are first treated with fertility drugs. A cow will then produce up to eight eggs, a process known as superovulation. The eggs are fertilized by AI in the usual way and are then washed out of the womb with a sterile solution before they become implanted in the womb lining.

The solution is collected in a sterile bottle and the fertilized embryos separated out under a microscope. Most are used immediately on the same farm, but spare ones can be frozen in a portable storage unit in the same way that sperm is. These embryos can either be used later on the same farm or sold to another farmer. Some are even exported.



John Houghton

An embryo grows *into a group of cells known as a morula by the time it reaches the womb or uterus (1). Up to this point it is simple to remove the embryo from the mother either by surgery, or by flushing, in the case of some animals. The cells are then re-arranged to form a hollow ball known as a blastocyst (2). This starts to pick up nutrients from the womb lining and steadily burrows (3) into the womb lining, until it cannot be removed without destroying the future life.*

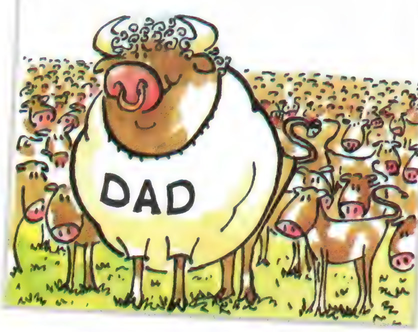
Geoff Tompkinson/Aspect Picture Library

Embryo flushing *is normally done by a team of vets. The sterile fluid is injected into the womb and allowed to drain back into a container. Apart from a slight discomfort, the cow does not suffer.*

Just amazing!

A LOAD OF BULL

ONE BULL'S SEMEN OUTPUT FOR A YEAR IS WORTH UP TO £1 MILLION AND WILL FERTILISE UP TO 100,000 COWS.



Paul Raymonde

This is a quick way of improving the quality of a herd because the fertilized embryos are implanted in healthy but unproductive cows. The resulting calves will then have the characteristics of the choice animals that provided the sperm and the egg, not of the animal that actually gave birth. Another advantage of this method is that it is non-surgical, so the cows do not get upset and the success rate is therefore high.

Immature eggs

Several new reproductive techniques are now being developed, mainly for cattle. One of these is *in vitro* maturation. A cow – usually an old one – will be selected and sent for slaughter. The ovary will be removed from the carcase and large numbers of immature eggs extracted from the ovary. These are placed in a liquid containing similar foods to the ones supplied to the eggs in the ovary. The eggs go on growing and microscopic examination reveals when they are mature and so ready for *in vitro* fertilization. The fertilized embryos are then implanted in a suitable cow.

Another technique of the future is the division of a normal fertilized egg into two separate embryos. Soon after fertilization, the nucleus of the egg divides into two, each part with a full set of chromosomes.

Under a microscope, this single cell can be cut in half with a small piece of razor blade leaving one nucleus in each half of the cell. New cell membranes form round each half egg and these grow into separate but identical embryos, ready for implantation. The embryos grow into two separate but identical animals, each one a clone of the other.

In theory, each of these new embryos could be divided again and again, but this does not always work. Another technique, which is likely to be more successful, is nuclear transfer. In this, the original embryo produced by a selected bull and cow is allowed to go on growing until it is a cluster of cells. Several of the nuclei of these cells are then removed and microinjected into ordinary cattle eggs from which the original nuclei have been removed.

Avoncroft Cattle Breeders Ltd

Semen for export *is tested with extra care to prevent cattle diseases being spread from country to country. It travels in insulated containers.*

Geoff Tompkinson/Aspect Picture Library

Embryo splitting *produces cows which are clones of each other. Nevertheless, minor differences, such as different-shaped patches, do appear.*

Avoncroft Cattle Breeders Ltd

Semen doses *are tested and diluted with sterilized skimmed milk, then frozen in a computer-controlled freezer unit.*

All the genetic information of the superior animal is in the chromosomes packed into the transplanted nucleus. The new cells develop into identical embryos.

Life is normally thought of as fragile and easily damaged. But these reproductive techniques are becoming routine, so eggs and sperm must be tougher than we sometimes think.

SEXING EMBRYOS

Farmers sometimes want female calves for milking; at other times they might want male calves for fattening up ready for slaughter. Embryos for transplantation can be tested for their sex before being implanted in their new mothers. A special dye is added to the embryo container. If the embryo is male, the dye will cling to the outisde of the cell coat and stain it. Perhaps the researchers could fix it so that embryos are coloured blue for a boy, pink for a girl.

TIME TRAVEL

Stephen Hunt/Image Bank

Time travel is still a fiction for Man, but modern ideas about the Universe depend on the way time speeds up and slows down.

IN THE 21ST CENTURY, a starship returns to Earth from a mission to the star Wolf 359, which lies 7.5 light years away. The ship's log records a successful trip lasting 15 years, with the ship cruising at 99 per cent of the speed of light. On board, all is well.

But crew members cannot recognize any of the faces among the crowd assembled to greet them. For back on Earth, 106 years have passed during the voyage and the crew's families and friends have all died. . . . The reasons is that time on the swiftly speeding starship has been passing seven times more slowly than on Earth. The ship's crew have travelled into the future.

Starship time

This is not the product of a science fiction writer's imagination – it would really happen, according to the laws of nature. Aboard the starship, time is measured by clocks, all of which indicate that only 15 years have passed on the trip. No one aboard the spaceship would notice any difference from normal time on Earth. Bodily processes, such as the rate of their heartbeat and ageing, would also slow down by the same amount as their wristwatches. Only when they returned to Earth would the results of the time difference before noticeable.

The key to understanding this difference is the speed of light. Light always moves at 300,000 km per second – the fastest speed in the Universe. You would always measure the speed of a beam of light to be 300,000 km per second, no matter whether you were moving towards the source of the light beam or away from it.

Speed of light

This appears to defy common sense. For example, if you measured the speed of an object such as an oncoming car, the closing speed would be equal to your speed plus the speed of the oncoming vehicle. But that does not work in the case of light. Your own speed does not affect the speed at which light is moving relative to you.

Earlier this century the physicist Albert Einstein realized that if the speed of light is constant, then the passage of time must be variable, depending on *your* speed. He concluded that the closer you travel to the speed of light, the slower time passes. This effect is known as *time dilation*.

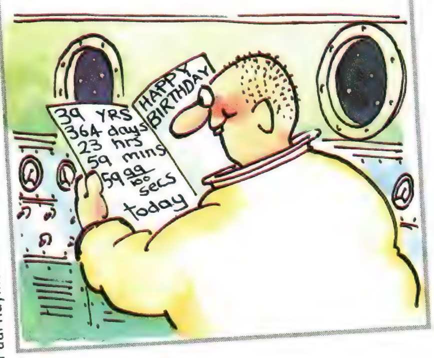
In the case of our imaginary starship cruising at 99 per cent of the speed of light, time would pass at one-seventh the rate that it does on Earth. At the speed of light itself, time would stand still – but, according to Einstein's theory, it is impossible ever to reach the speed of light. It is the speed limit of the Universe.

As time slows down, other effects come into play, too. The length of the starship – and of the objects and people inside it – becomes shorter in comparison with

Just amazing!

COSMIC YOUTH

A COSMONAUT LIVING ON A SPACE STATION WILL AGE MORE SLOWLY THAN SOMEBODY LIVING ON EARTH. THE DIFFERENCE IS ONE HUNDREDTH OF A SECOND PER YEAR.



Paul Raymonde

their length back on Earth. What's more, the mass — known as weight on earth — of the starship and its contents also goes up. The same factor that governs the slowing of time also applies to the shortening of length and increase of mass.

As the speed of light is approached, length shrinks towards zero and mass increases towards infinity. As with the slowing of time, the people on board the spaceship notice nothing abnormal since everything is changing by equal amounts.

At normal everyday speeds on Earth, such as in a car, these effects are so tiny as to be totally unmeasurable. Even a spaceship orbiting the Earth moves at only about one forty-thousandth the speed of light.

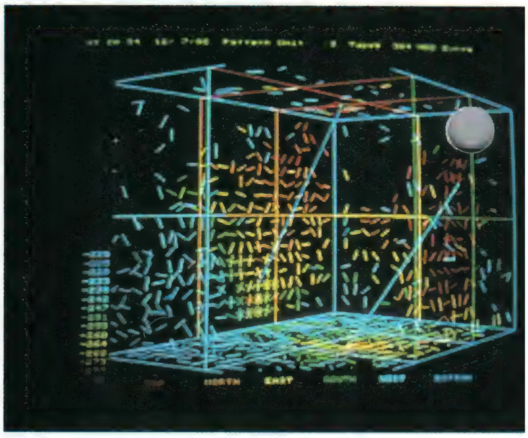
SLOWING TIME

Time slows down as we approach the speed of light. This table shows how much time would slow, relative to clocks on Earth, at various percentages of the speed of light.

Percentage of the speed of light (relative to Earth)	Amount by which time is slowed, relative to Earth
0	1.000
10	1.005
20	1.021
30	1.048
40	1.091
50	1.155
60	1.250
70	1.400
80	1.667
90	2.294
95	3.202
99	7.089
99.9	22.361
99.999	223.607
100	Infinite

A STRETCH IN TIME

The slowing of time at high speeds is shown by tiny particles, smaller than atoms, called mesons. These occur when cosmic rays strike the Earth's upper atmosphere. Mesons have a lifetime of two millionths of a second, during which time they travel about 600 metres – nowhere near enough to reach the Earth's surface. But time dilation enables mesons to reach the surface, where they can be detected by a cosmic ray detector (right). To a meson travelling close to the speed of light, the 40km of the earth's atmosphere is no more than a few hundred metres deep.



Larry Sulak/SPL

Cosmic rays

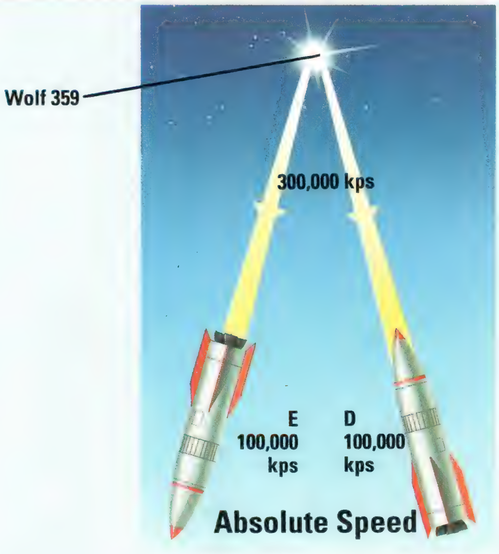
However, we can see the effects of time dilation at work in the case of atomic particles that are travelling close to the speed of light. These particles come from space in the form of cosmic rays. (We can also speed up atomic particles in machines on Earth called particle accelerators.) Such fast-moving particles have a much longer lifespan than normal and an increased mass — as predicted by Einstein.

If we could travel as close to the speed of light as these atomic particles, time on our spaceship would slow down so much that we could cross the Galaxy in a human lifetime. Back on Earth, 200,000 years would have elapsed.

Therefore high-speed space travel offers a form of time travel, with potentially bizarre results. For example, you could take off on a trip lasting 60 years of Earth time. When you returned, you might have aged only a few years — yet your son, only a toddler when you left, would by then be an old man!

This form of time travel, however, is fast forward only — into the future. There is no going back.

THE CONSTANT SPEED OF LIGHT



Caroline Brodie

Imagine that you are driving along a motorway. If you were travelling at 100 kph (kilometres per hour) in car A and car B came towards you at 100 kph, the two cars would approach each other at 200 kph.

If car A continued moving at 100 kph and overtook car C travelling at 80 kph, the difference in speed would be only 20 kph. So although car A is always moving at 100 kph, its speed *relative* to other cars depends on the direction they are moving in.

However, suppose you were in starship D, travelling towards the star Wolf 359 at 100,000 kps (kilometres per second). If you measured the speed of light from the star coming towards you, you would get a reading of 300,000 kps. And if somebody on starship E speeding away from Wolf 359 at 100,000 kps measured the speed of light, they would also find that light from the star came towards them at 300,000 kps. So the speed of light is *constant* no matter what direction you happen to be travelling in.

WATER POWER

- TURBINES
- TIDAL POWER
- EROSION

ANCIENT WATERWHEELS have been transformed into huge modern turbines. These lie at the heart of hydroelectric plants driven by water power – the most economical method of generating electricity.

Hydroelectric turbines are powered by the huge reservoirs of water held back by dams. As the water falls through the power station, the turbines turn and electricity is generated.

Hydroelectric power is clean, inexpensive and safe. Some countries, notably Norway, derive nearly all their electricity from this natural source.

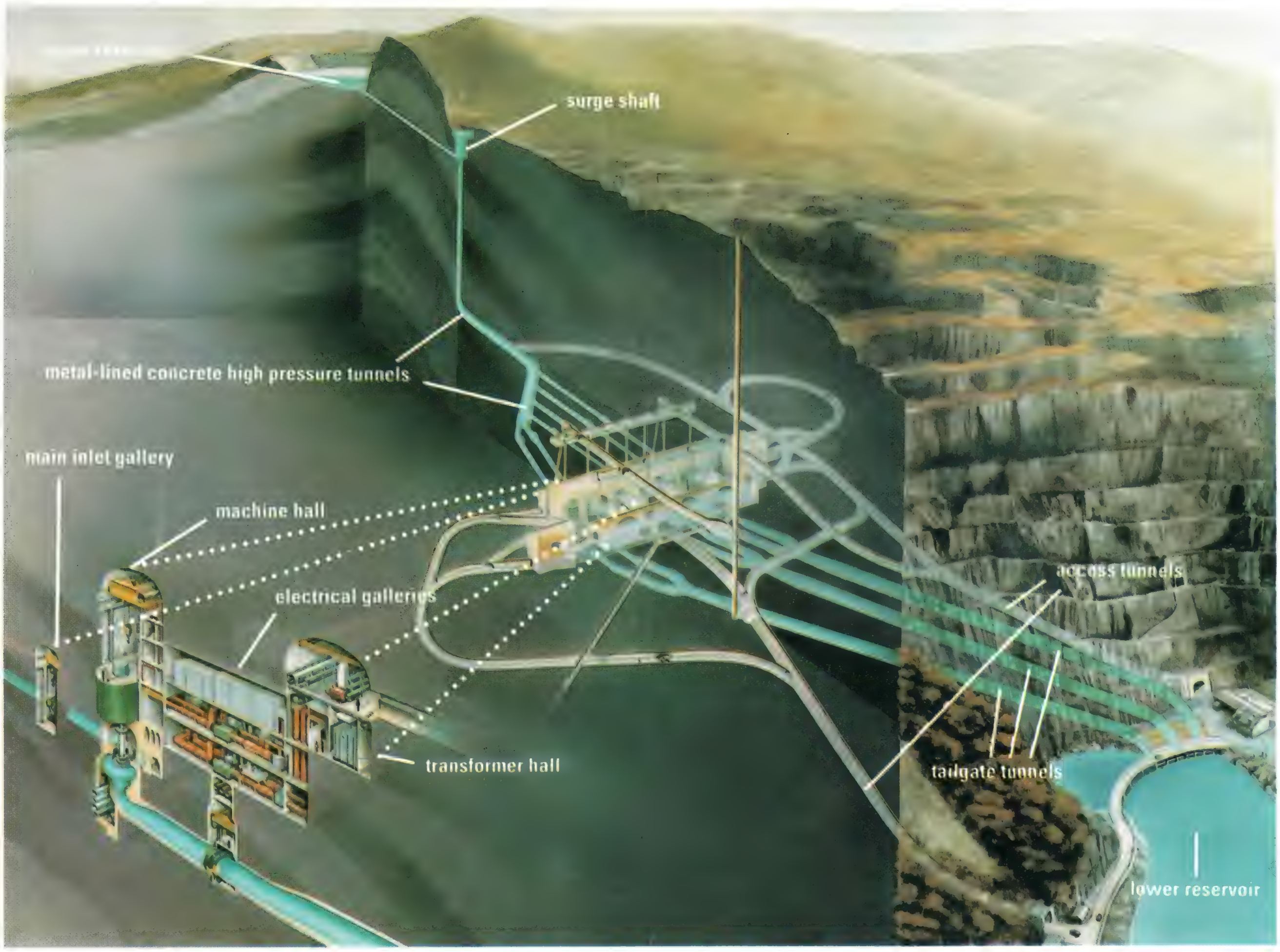
About five different dam designs are in common use today. They range from the 'solid gravity' design of the world's highest dam in Tajikistan which resists the massive pressure of the water behind it simply by its huge mass, to the cupola dam which has great strength because of its curved shape. Cupola dams are usually built across narrow valleys; the curve of the dam directs the huge thrust of the water into the solid rock walls of the valley.

More than one type of turbine is used. Reaction turbines are the most powerful. They have propeller-like blades inside a curved outer casing and are completely immersed in the stream of water.

Under pressure

If the volume of water is not large but comes at a high pressure because it falls from a great height, an impulse turbine is used. This type is called a Pelton wheel. The wheel is driven round by the impulse, or force, of water jetting into cups arranged around the turbine.

__Niagara Falls__ was harnessed by the world's first ever hydroelectric power station. The turbine room of the modern hydroelectric power station at Snettisham, Alaska, (inset) can produce over 47 megawatts, enough to serve a small town.



Central Electricity Generating Board

***The pumped-storage** power station at Dinorwic, Wales, uses turbines to pump water up to the top reservoir. Running it back generates electricity.*

Water turbines can also be used to generate electricity from the power of the tides. The only large tidal power station is on the estuary of the River Runce, in Brittany, France, which has an average tidal range of over 8 metres. A dam across the estuary holds back the water, creating 'a head' to drive the turbines.

Some tidal systems have a double action, rotating the turbine in one direction when the tide flows in, and in the opposite direction when it ebbs. Other systems use only the ebb (outgoing) tides.

Although huge ocean waves carry with them massive amounts of energy, no cheap and easy way of recovering it has yet been devised.

Wave force

However, small-scale, experimental schemes have been put into practice. A prototype 'oscillating water column' wavepower generator is to be built on the Island of Islay, off the west coast of Scotland.

The column is a chamber submerged and open to the sea at the bottom. As waves wash past, the water inside moves up and down like a piston, driving the air above in and out through a turbine. A system of valves makes sure that the turbine always turns the same way. The turbine itself is connected to a generator which creates electricity.

The prototype on Islay will generate 180 kW, enough to supply local houses at 4p a kWh, 35 per cent cheaper than electricity on the mainland.

Coal-fired, oil-fired and nuclear power stations rely on turbines to harness the power of steam produced in boilers into electricity. These enormous steam turbines are driven by high-pressure steam at high temperatures. The steam entering turbines is around 550°C and the pressure as high as 350kg/sq cm.

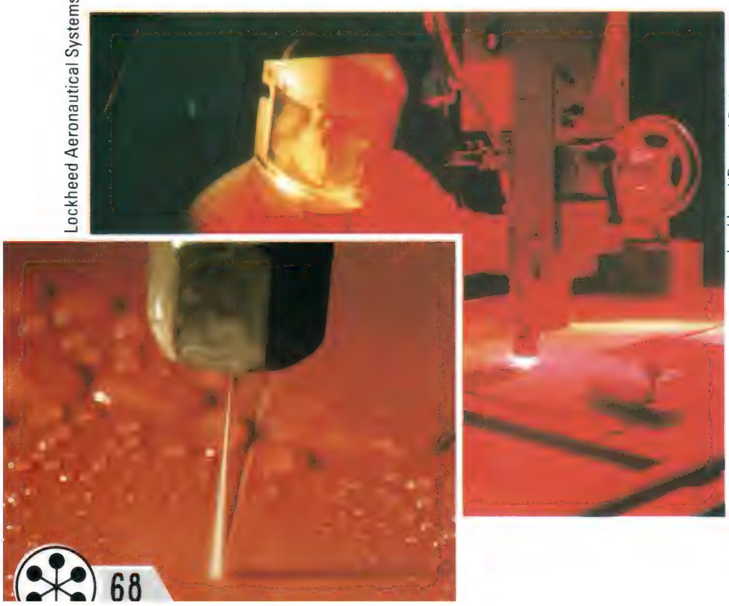
In the 60 Hz system used in the USA, turbines run at 3,600 or 1,800

ZEFA

***Hydroelectric dams** generate electricity, which is controlled by a complex system of transformers and switchgear.*

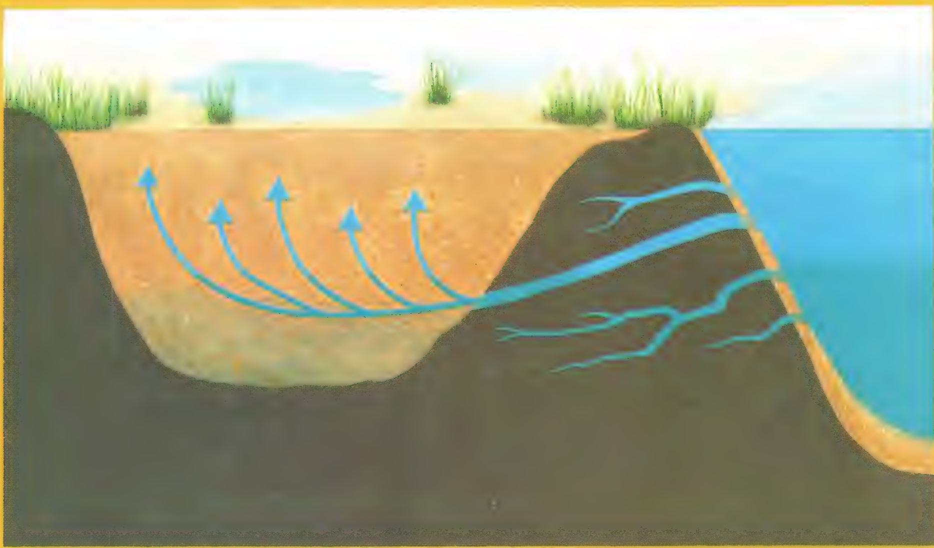
Lockheed Aeronautical Systems

Lockheed/Dept of Defense/TRH



***Jets of water** containing fine particles of the gemstone garnet can cut through aluminium. The water cools the metal as the particles cut it, so the edges are not distorted by friction.*

THE SECRET OF QUICKSAND



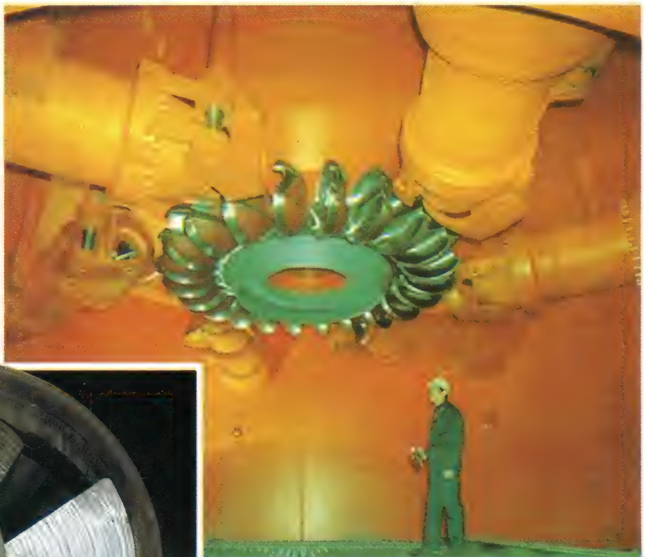
Caroline Brodie

There are few more horrible deaths than being drowned in quicksand. Ground that looks solid suddenly gives way, sucking you down into crushing, choking extinction.

But quicksand is living testimony to the power of water. It is not simply a pit of dry soft sand. Nor is it wet sand that is just particularly soggy. Quicksands are created when water from an underground spring forces its way up through a pit of sand. The water pressure forces the grains of sand to separate slightly, turning normal sand, which is safe to walk on, into an inescapable, crumbling, sinking hell.

rpm (revolutions per minute). In the 50 Hz systems used in Europe, speeds are 3,000, 1,500 and 1,000 rpm. At such speeds, steam passes through the entire turbine in less than 1/30th of a second – the time it takes to blink.

The amount of energy supplied to a hydroelectric power plant is determined by the volume of water stored behind the dam or natural reservoir. When the demand for electricity is low, water passing through the turbine is wasted and any electricity generated unwanted. Shutting down the turbine is time consuming and uneconomical. The problem is that, as yet, there is no method of effectively storing large amounts of electricity.



Kvaerner Boving Ltd

***An impulse turbine** is turned by high-pressure water jetting into its cups. A reaction turbine (inset) is submerged in the stream and is turned by the water rushing past it.*

Kvaerner Boving Ltd

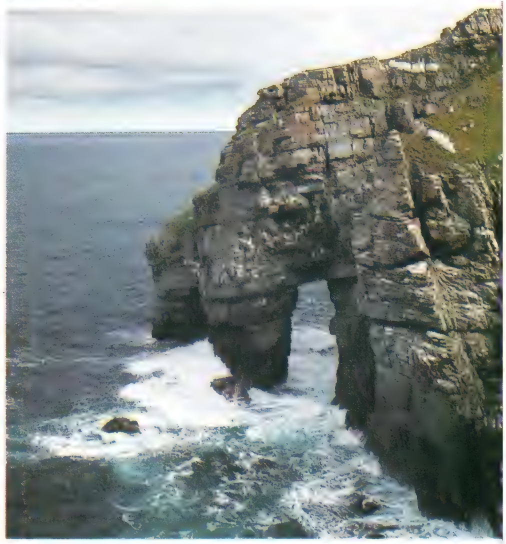
One way around this is to use pumped-storage, as at Britain's new plant at Dinorwic in Wales. The plant is sited in mountains close to two lakes located at different heights.

At night and during other off-peak periods, surplus electricity is used to power pump turbines which raise water from the lower lake to the upper one. During the day, when demand for electricity is high, the water is allowed to fall again from the top lake down into the bottom one through the turbines, generating extra power just when it is needed.

Hydrogen fuel

Hydrogen is the most abundant element in the universe, and it can be made by splitting molecules of water, which release oxygen at the same time. Already liquid hydrogen is used as a fuel in the main engines of the Space Shuttle and in other space rockets. However, this cheap, clean fuel could have more widespread applications on Earth.

ZEFA



***The power of the waves** is enough to crumble even solid rock. They force air into cracks with explosive power.*

Just amazing!

PELLETS FROM HEAVEN

SEEDING CLOUDS WITH PELLETS OF DRY ICE CAN SET OFF RAIN OR SNOW STORMS. A SINGLE PELLET FALLING THROUGH A CLOUD 1 KM THICK COULD PRODUCE AS MUCH AS 100,000 TONNES OF SNOW.

Paul Raymonde

In Russia, scientists are experimenting with liquid hydrogen for use as an alternative fuel in Tupolev airliners. Burning the liquid hydrogen poses no special problems – it combines with oxygen to form water vapour and give a clean, hot exhaust.

Fuel space

Although liquid hydrogen burns cleanly and causes less engine wear, it unfortunately has certain disadvantages. It takes up four times as much space as liquid aviation fuel, so aircraft need extra large tanks. It also has to be kept at very low temperatures indeed – well below its boiling point, which is $-253^{\circ}C$. It would also be possible to run cars on hydrogen. Manufacturers have designed prototype cars, but the size and capacity of the fuel tank have again posed difficulties – along with the problems of insulation and safety.

Central Electricity Generating Board

***Each steam turbine** at the Drax coal-fired power station in Yorkshire, England can generate up to 660 megawatts at full power.*

NEI Parsons Ltd

***The main shaft** of a steam turbine rotates at about 3,000 revs per minute. It takes about an hour to reach this speed. Full electrical output is reached in 12 hours but the shaft gets so hot that if it were stopped suddenly, it would bend. To prevent this, the turbine is cooled over four days.*

Water power can also sculpt mountain ranges that were thrust up by enormous underground forces. As soon as they were formed, wind and rain and other weathering agents set about carving or smoothing them into the shapes we see today.

Rain water wears away the surface where it runs over it. In time, a fast-flowing river cuts a deep 'V' in a rock formation, often exposing deeper layers in its structure.

Where water freezes in rock cracks, it can split off tiny flakes or even large boulders. And, on a larger scale, huge glaciers of ice slowly and relentlessly slide downhill, grinding the rock away.

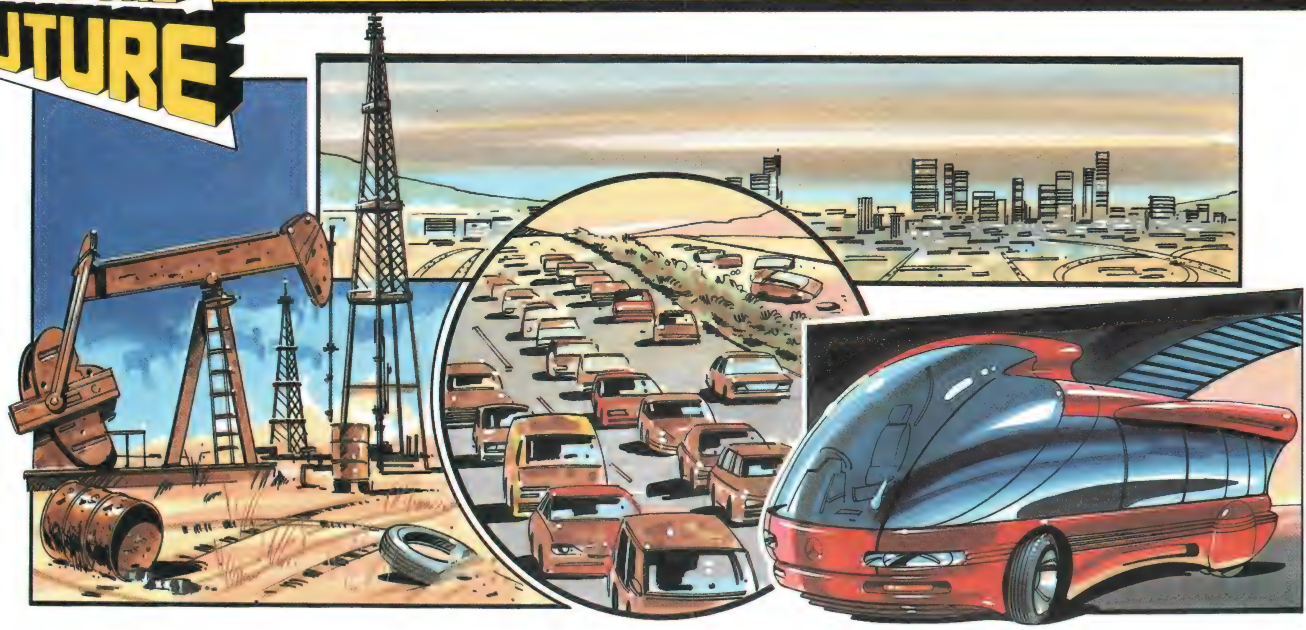
Breaking rocks

At the shore line, crashing waves can exert enormous force on cliffs. Waves can move boulders weighing more than 1,000 tonnes from rock faces by compressing air into cracks in the rock. The air expands with explosive force.

Erosion by water has also been developed into a new tool. Abrasive gemstone particles in a water jet can cut through aluminium. Although a gemstone abrasive cuts by friction, the water cools the cut, preventing heat distortion.

INTO THE FUTURE

RUNNING ON WATER



▲ The Earth's reserves of fossil fuels, like coal and oil, will one day run out. So there will be no petrol to run cars.

▲ Burning hydrogen which is derived from water, is a good alternative and – unlike petrol – it is non-polluting.

▲ Experimental vehicles have already been built, with hydrogen-burning engines, which are 50 per cent more efficient than diesel.

Joe Lawrence

New synthesized music rivals a traditional orchestra in its fullness and the complexity of sound. Equally amazing, an orchestra of electronic instruments may be controlled by just one musician.

ZEFA

David Redfern

SYNTHETIC SOUND

NEW MUSICAL TECHNOLOGY has revolutionized music making. A synthesizer can produce the sound of a church organ, of breaking glass, of a trumpet, or electronic sounds no human ear has ever heard before – or all these together.

A synthesizer is an electronic instrument that can remember instructions and on which sounds can be edited. It puts together the things that make up a sound. (To synthesize means to put things together.) It is usually keyboard based.

Any sound has four essential qualities:

- **pitch** – how high or low a note is
- **timbre** – the character of the sound (what makes a saxophone sound different from, say, a violin)
- **volume** – how loud the sound is
- **envelope** – how its volume and timbre change over the time it is heard.

Shaping a note

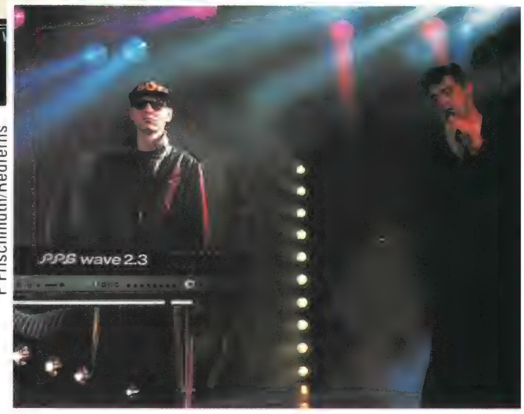
Not only does a synthesizer put these components together, it also alters them so that exactly the sound the player is after is produced. It then transmits the sound, in an electrical signal, to the amplifier and speakers.

An analogue synthesizer shapes each sound by taking away the unwanted elements of the basic waveform. When playing an analogue synthesizer, the most important controls, which shape the pitch, timbre and volume of the note, are:

- **the Voltage Control Oscillator**, which produces the original sound when a key is pressed on the keyboard.
- **the Voltage Control Filter** is

Casio Electronics Co Ltd

'Synth-pop' groups are products of the synthesizer revolution. Erasure (Vince Clarke and Andy Bell) and Pet Shop Boys (Chris Lowe and Neil Tennant, below) both consist of one musician, who plays all the music on a synthesizer, and a vocalist.



P Frischmuth/Redferns

then set to filter out some of the frequencies that make up the original wave. This gives the sound its 'timbre' – its individual character.

- **the Voltage Control Amplifier** controls the volume of the note.

As a key is pressed, the sound created quickly rises in volume, and then the volume drops slightly. The sound is sustained as long as a finger continues to press down the key. When the key is released, the sound fades away. How the volume of the sound changes is controlled by a 'volume envelope generator' within the VCA. An envelope generator within the VCF controls the development of the timbre of each sound.

SPEAKEASY

Synthesizer: an electronic instrument that creates sound electronically and on which sounds can be edited
Analogue synthesizer: every change in a sound is caused by altering an electric current
Digital synthesizer: every sound is chopped up and stored as a string of ones and zeros called binary digits or 'bits'
MIDI (Musical Instrument Digital Interface): a communications system by which electronic instruments, samplers and sequencers can send information to each other
Sampler: a machine that records a sound and plays it back
Sequencer: a machine that records a sequence of key depressions and plays it back.

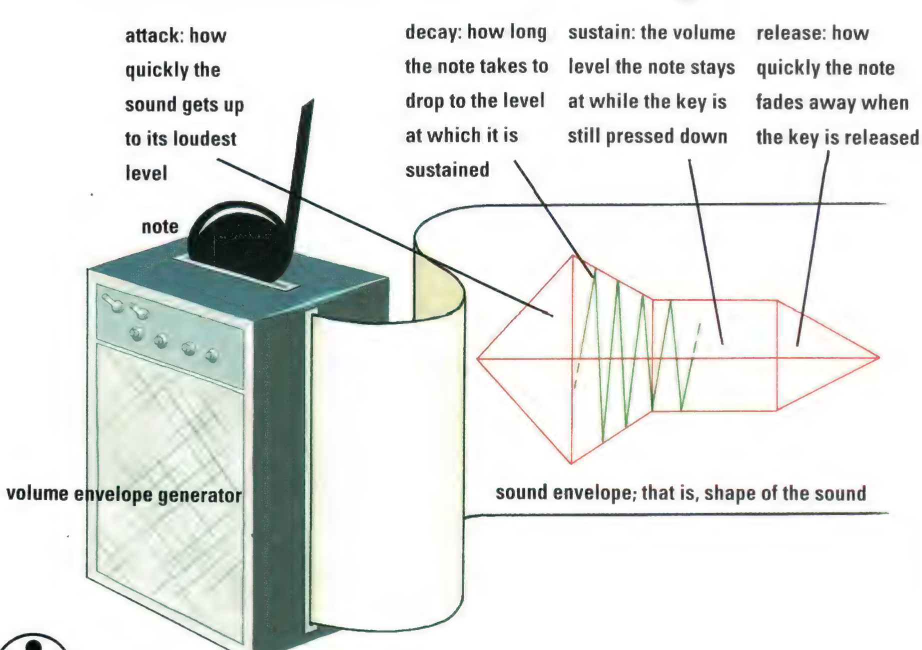
Music by numbers

The latest synthesizers are digital. These store and produce sound digitally – as a series of numbers. A digital synthesizer builds a sound up, by adding wave on to wave, to get the effect that is wanted.

There are several ways that digital 'synths' can operate. One is by using Fast Fourier Transform (FFT). This is a method whereby notes are broken down with great accuracy into the frequencies that make them up. FFT enables you to define a sound, and then to change any details so that precisely the desired effect is obtained.

Another digital method is FM – frequency modulation. FM synthesizers work by using waveforms as 'operators'. You set the first operator so that it sends out the first waveform. Next, you add the second operator, which has been set to give a different waveform. Putting the two together creates a new, complex waveform. You can keep on adding operators, up to a maximum of six, until you get the desired result – the exact sound

***A volume envelope generator** is a device that shapes the rise and fall of a note. It controls the four phases of each sound: attack, decay, sustain and release.*

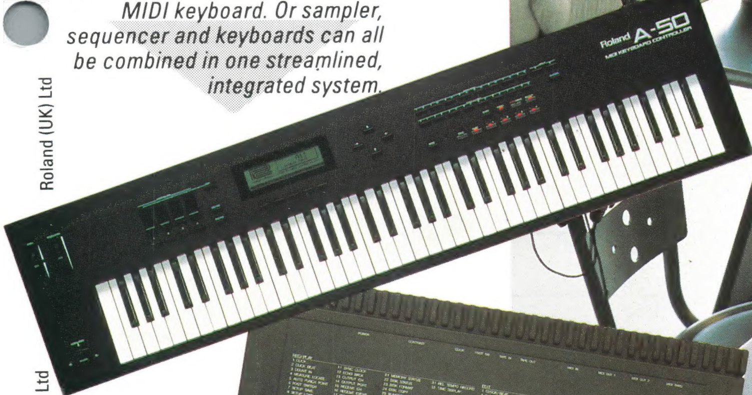


Caroline Brodie

SOUND AND VISION

These days you can do more with a compact disk than just listen to it. Among the most exciting uses of CDs at the moment are the following:

- **CD-ROM**: The CD has a prodigious data storage capacity – up to 600 megabytes or more – and this facility is now being widely used to store the texts of books, encyclopedias, and published data of all kinds. The resulting disk is called a CD-ROM (Compact Disk-Read Only memory).
- **Multimedia CD-ROM**: This advanced version of the CD-ROM is capable of recording speech, music, animations and video and movie footage.
- **CD-i**: This is an interactive version of CD-ROM which allows you to influence what happens on screen.
- **Photo CD**: Typically 100 of your favourite photographs can be recorded as digital signals on a CD.
- **CD Mini Disk**: This pocket-sized CD system uses a disk only 64mm in diameter. You can record on the Mini Disk, as well as play is back.



***Thanks to MIDI**, a sequencer and a sampler may be bought separately, from different manufacturers, (as you can afford it) and plugged into one system, which you control from a MIDI keyboard. Or sampler, sequencer and keyboards can all be combined in one streamlined, integrated system.*

Roland (UK) Ltd

Roland (UK) Ltd

Yamaha

Roland (UK) Ltd

COMPUTER ON PIANO

Donna Coveney/MIT Media Lab

An instrument can now be played in a live performance – by a computer. In one concert, Lucy Stolzman played the violin and a computer accompanied her on the piano.

How was it done? A digital recording was made of a pianist playing the keyboard part and the recording stored in the memory of a computer. On stage, beside Lucy Stolzman, stood a piano, on which the computer played back the recording.

But how did the computer know when to join in? It picked up the sound from the violin, pinpointed the exact note on which to come in, and began to play. It was important, therefore, that Lucy Stolzman did not play too differently in pace and style to how she played when the accompanist was being recorded by the computer a few hours before the concert.

that you want. Each operator has its own envelope generator, so that the character and volume of each sound can be very carefully controlled.

Sound appeal

Every make of synthesizer has its own individual sound. In general, the older analogue synthesizers have a full 'fat' sound (which musicians often prefer) compared to the clean, sharp notes of most digital machines. Analogue-digital hybrids have been built by adding a microprocessor to an analogue synth.

A 'sampler' can be a separate piece of hardware or part of a digital synthesizer. Samplers are actually digital sound recorders that record 'real' sounds. The recording, for example, of a musical instrument, can be rearranged as desired, then played back as part of a musical composition.

Making tracks

You can build your own song, using samples of any instrument you want. This is done on many hit songs in the charts today. Sampling increases the range of a synthesizer from electronic sounds to every 'natural' sound that can be recorded.

Synthesizer manufacturers got together and devised a system called MIDI – Musical Instrument Digital Interface – so that synthesizers or electronic instruments, such as

drum machines, could be linked together, regardless of make. MIDI consists of cables through which commands can be transmitted. Each end of the cable can be plugged into a different machine.

Fingertip control

MIDI possesses 16 communication channels – an instrument must be tuned to the correct channel, or it will not receive the instructions that are being transmitted along the cable. Each channel can transmit any number of notes to any number of instruments. Sitting at a single keyboard, you can control a whole orchestra of electronic instruments.

Another piece of hardware, which can also be built into a digital synthesizer, is a sequencer. Like a tape recorder, a sequencer will record anything played on it via a keyboard. However, unlike a tape recorder, it does not record the sound of the notes. It records the information that you give when you press a key; that is, what note is pressed, how hard it is pressed and how long it is pressed. This information can be stored in the sequencer's memory.

As you play back the recorded sequence of 'key depressions' on an electronic instrument, the sequencer 'plays' the electronic instrument, telling it what notes to play, how hard and for how long. When building up the backing track for a song, a sequence can be stored for the drums, the bass, and the keyboards – in fact up to an incredible 200 tracks on some of the latest sequencers.

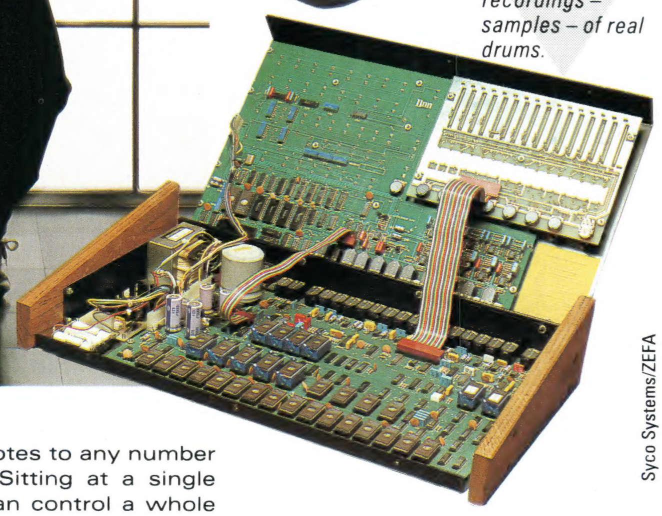
Using MIDI, electronic instruments can play all the different sequences together. The effect resembles a group or an orchestra. So when you hear a piano, a brass section and a string section over bass and drums on a chart hit, the instruments may have originally been sampled, and exist only as data on a sequencer.

With a guitar synth you can play electric or acoustic guitar, or jazz organ, or even the trumpet. When plugged into MIDI, the guitar can control other instruments.

Casio Electronics Co Ltd

One digital horn can reproduce the sounds of a saxophone, trumpet, oboe, clarinet or flute.

Casio Electronics Co Ltd



A drum machine uses digital recordings – samples – of real drums.

Syco Systems/ZEFA

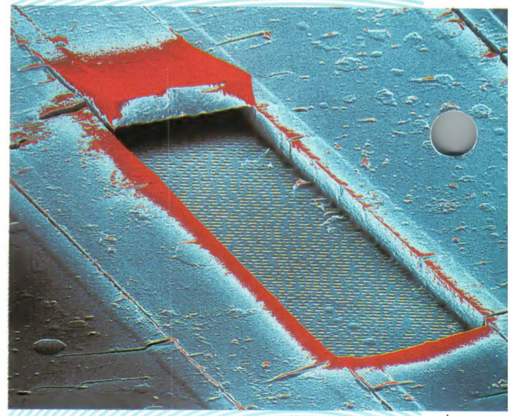
Good vibrations

Synthesizers do not necessarily have a keyboard. There are also guitar synthesizers – like some keyboard synths, these can be slung around the performer's neck, giving him or her the freedom to walk around.

There are even wind synthesizers, which look like saxophones. In these, the air vibrations produced by the player are turned into digital signals and sent on to a synthesizer unit.

All these different synths can be connected up through MIDI to play other synthesizers. Synthesizers controlled through MIDI may even just look like a box, because there is no need for them to have keys at all.

INSIDE A COMPACT DISC



False colour scanning electron micrograph of a compact disc cracked to show the base layer below the outer plastic covering. The base layer is made of plastic, which is pressed with a series of fine depressions. Each depression represents a digital musical signal capable of being read by a laser beam. To reflect the laser light, the base layer is coated with a fine film of metal, which follows the depressions exactly. This layer is covered by another layer of transparent plastic. The base layer is sealed between two layers of plastic, which prevent dust and scratches from affecting the sound when the CD is played.

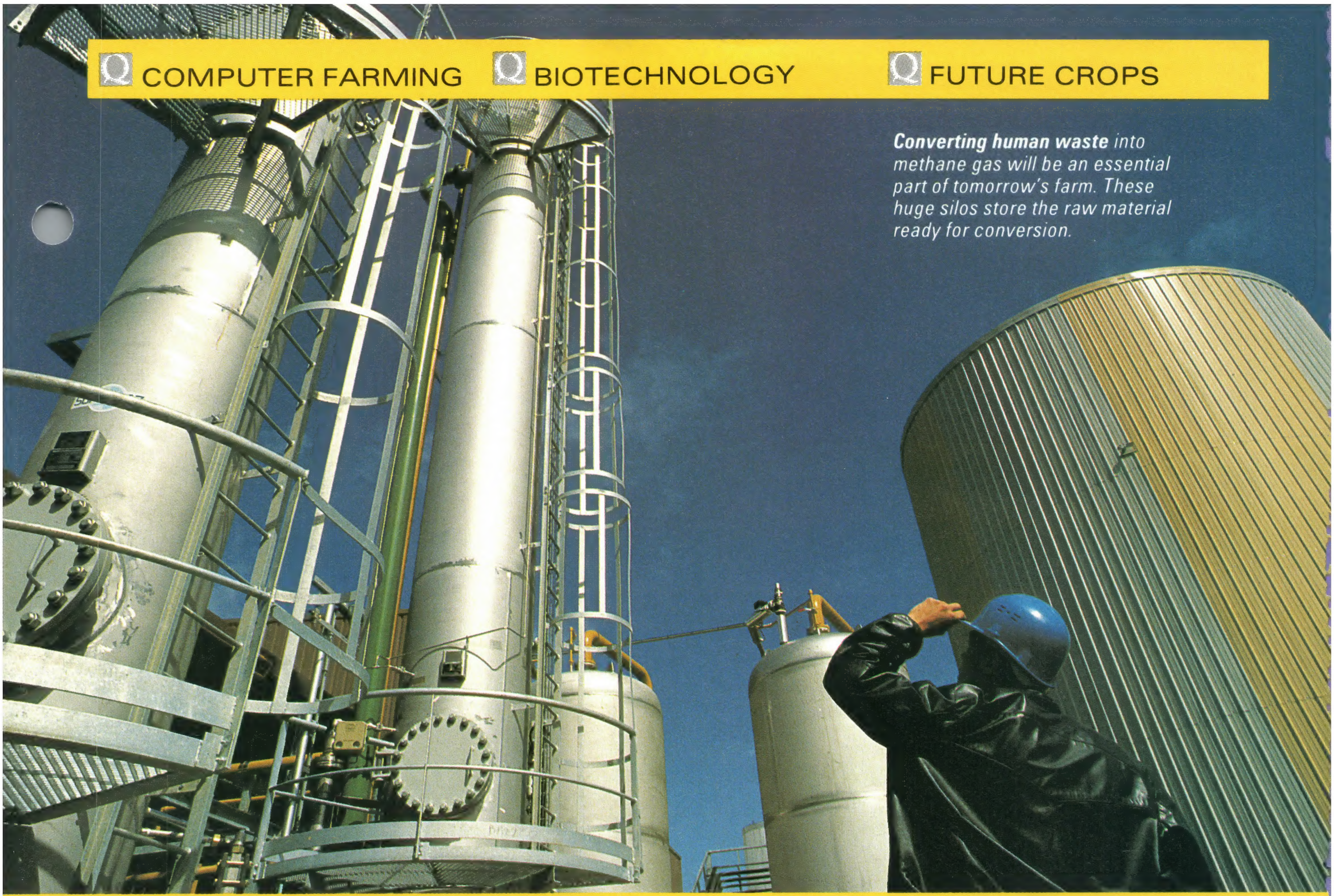
Dr Jeremy Burgess/SPL

Just amazing!

GIG OF THE CENTURY

IF YOU SAT DOWN AT THE LATEST SYNTHESIZER AND PLAYED EVERY SOUND IT COULD PRODUCE, YOU WOULD STILL BE THERE IN A HUNDRED YEARS' TIME.

Paul Raymonde



***Converting human waste** into methane gas will be an essential part of tomorrow's farm. These huge silos store the raw material ready for conversion.*

Pascal Nieto/Jerrican

FUTURE FARMING

FARMS ARE CHANGING with the times. Today's farmers are likely to link their desktop computers along phone lines to the local weather centre for updates on temperature, wind and humidity levels, plus the latest short-term forecasts.

At the same time, automatic sensors in the fields send data about soil temperature and moisture content to be fed directly into, for example, a wheat-growing programme, to see if and when the irrigators should be switched on.

One area which is taking great strides is plant technology. It is a long and costly business growing and harvesting plants in the wild and then extracting the parts you need. Biotechnologists can now take a plant and isolate the cells they want, and then grow them in a huge vat under controlled conditions. The soupy liquid in the vat is called a 'tissue culture'.

Success story

In Japan, a red dye called shikonin is used in cosmetics such as lipsticks. Traditionally the dye has been harvested from the roots of a five-year-old plant. But 1 kg of plants yields only 10 grams of dye, and so it was very expensive. Now one Japanese company makes the dye in tissue culture and can sell it 30 per cent cheaper than the current market price.

The most exciting project in this area concerns cotton. One American biologist has discovered a way to grow cotton fibres in the laboratory which is far more efficient than the conventional method. Billions of cells are wasted as leaves, stems and roots in the cotton plant, but only the cotton fibres are wanted.

Safe and speedy

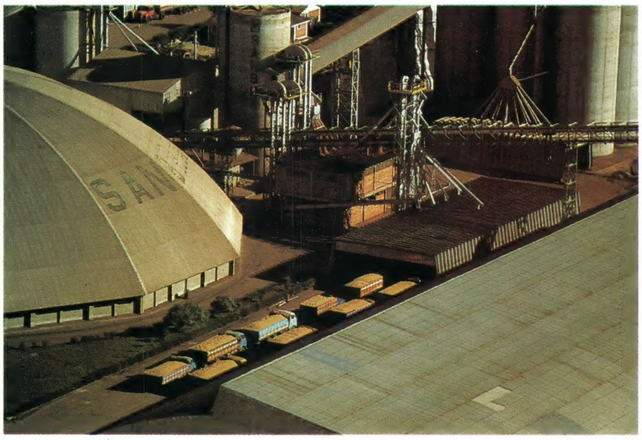
In the test tube, every cell becomes a fibre, and the whole process takes only half the time. Other benefits are that the cotton is free of the bugs that cause 'brown-lung' disease in textile workers, and fibres can be grown to a specific strength

Just amazing!

LEAN BACON

AN AMERICAN SCIENTIST HAS DEVELOPED A LOW-FAT PIG. WHEN HE INJECTED PIGS WITH GROWTH HORMONES, THEIR BODY FAT FELL BY 80 PER CENT, WHILE MUSCLE (MEAT) ROSE BY 50 PER CENT.

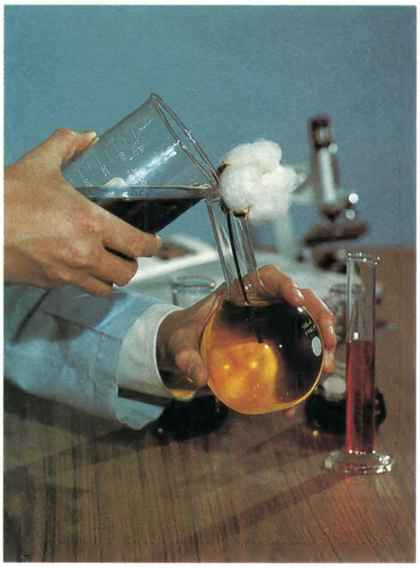
Paul Raymonde



Nicholas Devore III/Bruce Coleman Ltd

***Soybeans** are big business. At this giant factory in Brazil, trucks unload huge quantities of beans for processing into soya oil and flour.*

***Seeds** can now be planted in long biodegradable 'carpets', which are laid in the fields. There, they break down and the seeds grow normally.*



Little Publications Cotton Farming Magazine

***Test tube cotton** is an exciting example of biotechnology. Every cell becomes a cotton fibre and the process is far quicker than traditional cotton growing.*

and length, as required.

Versatile soya

The soya bean, or soybean, is the most important pulse crop in the world. (Pulses are peas, beans, lentils and similar plants.) Soybeans are high in nutrients, and could become the crop of the future.

Soybeans are pressed for their oil, which is low in the type of fats that contribute to heart disease. The beans can be ground into a flour, while the fibrous part can be 'spun' and flavoured to make meat substitutes. They are also used as animal feed and in industry to make plastics, artificial rubbers, soaps, paints and inks. Fermenting the beans with fungus has even produced a contraceptive drug.

Jojoba

Before the ban on commercial whaling, the sperm whale's oil had been used for years to make shampoos and cosmetics. But biochemists showed that oil from the jojoba plant, a shrub from the Sonora desert in Mexico, could do the job nearly as well. Now over 200 square km in the south-west of the USA are growing jojoba. The oil pressed out of the seeds is bought by cosmetic companies. But what about the 'meal' that remains? Some of its protein could be extracted and used

Ivaldi/Jerrican

to feed farm animals. Other parts have applications in the paper industry. Blocks of meal can serve as fuel for fires.

Waste-free buffalo gourds grow in dry regions of North America. The stems and leaves can be eaten by livestock. The huge roots contain starch, which can be used in cooking or changed into sugars. The seeds are rich in protein and oil, and when the oil has been extracted, the leftover meal can be fed to animals.

INTO THE FUTURE

THE AUTOMATED FARM

Joe Lawrence

▲ The farm of the future may be indoors, with genetically engineered plants growing in perfect conditions all year round. Light, heat and humidity would be computer-controlled.

▲ The whole process, from planting seeds to packing the harvested crops, would take place on huge conveyor belts, moving around the farm very slowly.

▲ Automation could mean that farmers need never get their hands dirty, but just monitor the computers and replenish supplies for the feeding systems.